METALLURGIA

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Heat-treatment of Steel Wire

By a Special Correspondent.

The various types of heat-treatment given to steel wire in the course of its preparation for various purposes is described in detail, and the various effects produced are illustrated by typical photo-micrographs which are all of wire in various gauges, and have been reduced by thirty per cent. in reproduction.

WHILST most of the properties of steel wire are generally attributed to the effect of the cold working which has been put upon the material, there is quite an appreciable amount of importance to be attached to the heat-treatment which has been given to the steel. The effect of this can be traced right from the time when the originally ingotic structure is broken down by the rolling to billet form, and subsequent reheating and re-rolling into the rod which is the basis of the final wire.

This heat-treatment may take quite a variety of forms, to which rather loosely applied terms are attached, sometimes quite erroneously, and with resulting confusion, which it is intended to clarify, even if there is yet no hope of having the definitions taken as generally accepted standards. The green rods from the mill are usually far from homogeneous, and where a soft-finished product is required, and even prior to equalising the size in a harder material, it is often good practice to anneal the uncleaned rod before the drawing is applied to bring the rod down to the final wire size. This kind of annealing, like that called an inter-annealing, is simply designed to soften the material sufficiently to enable the drawing to proceed, and may be accomplished with the rod or wire at a comparatively low temperature, around 600° C., provided it is slowly cooled afterwards. The term "lowneal" has been suggested for this operation, but does not appear to have been generalised. No change has been made in the crystal grain size of the material in this way, so that for structural alteration it is necessary to "highneal," or anneal at a sufficiently high temperature to bring the steel in question above the upper critical point, which depends upon its carbon content, and in this way grain refinement is brought about with corresponding physical properties. If cold-worked steel is, however, brought to a temperature even slightly below the necessary temperature, it is possible to effect a deterioration of the steel instead of an improvement, since either the grain size grows abnormally large, or slow cooling through the lower critical range brings about a change in the usual pearlitic structure, and the two constituents are "divorced" or separated, with undesirable results in most cases.

Annealing.

The method of carrying out these two operations may be varied almost indefinitely, the simplest method being in the open-flame furnace, which, however, is apt to develop rather heavy amounts of scale, and is not conducive to the best results when slow cooling is essential. The general practice both for "process" annealing as the softening treatment has been called, or the "full" annealing when grain refinement is desired, is to load the coils of rod or wire into a stout container, and perform the heat-treatment in this closed vessel in a gas-fired furnace. This entails the heating-up and subsequent cooling-down, either in the air or a gas-filled chamber to exclude air, of a much larger mass than the charge alone, and considerable economy of weight and space can be accomplished by the use of a portable electric box-oven to drop over the charge. Sometimes when a continuous process such as galvanising is to be applied to the softened wire, it is easy to arrange for a muffle or tube furnace to treat individually each wire before it passes to the cleaning tank and spelter bath following it. This is called tube annealing, and is really a kind of "process" annealing, as the wire does not attain or exceed the temperature of 700° C.

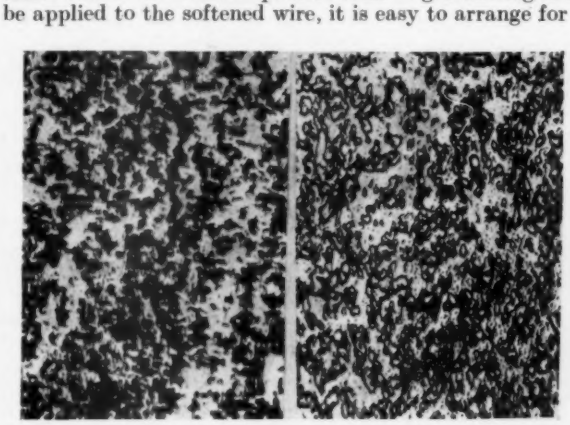


FIG. 1.—NORMALISED. 0·3% *carbon, small grain ferrite and pearlite.* × 200.

FIG. 2.—DIVORCED. 0·7% *carbon, massive cementite in ferrite.* × 500.

Normalising.

An important modification of the slow-cooling annealing is one in which the steel after being maintained for a suitable time, dependent upon its mass, at about 50° to 100° C. above its top critical temperature, is rapidly cooled in air. This is generally called "normalising," although it does not produce the normal structure of the steel, and Stead's "equalising" might have been a more suitable term, but never became popular. In addition to the grain refinement, which has been brought about by the temperature attained, the moderately rapid cooling produces a fine microstructure (Fig. 1) within the grains, particularly of the pearlite present, and this has very important effects upon the physical characteristics. In this way a structure is brought about which stands very drastic cold work, as in cold-heading or sharp right-angle bending, where the elastic limit of the material is over-passed, and in subjecting it to the common blue brittle range without the deterioration which would result in a steel not normalised. Wire which has been severely deformed, as in cold-heading from hard-drawn material, is very liable to be brittle, unless it is

FIG. 3.—SPHEROIDISED. 0·1% *carbon, atollic cementite in ferrite.* × 500.

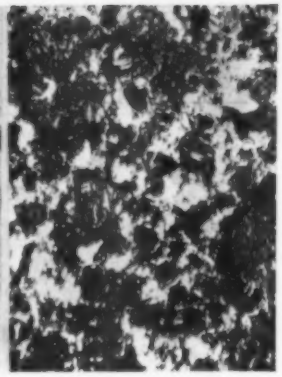


FIG. 4.—SORBITISED. 0·1% *carbon, diffused sorbite in ferrite.* × 100.

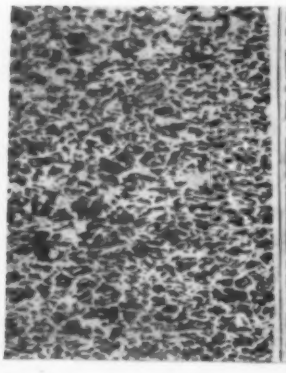
subjected to some form of normalising treatment, and if increased tensile properties are also desired, the normalising may be converted into oil quenching, which saves any subsequent tempering of medium carbons, as would be needed if they had been water quenched. Some of the higher carbons for spring work may be suitably quenched in oil, but for any subsequent coiling they generally need to be lead-bath tempered as well.

Spheroidising.

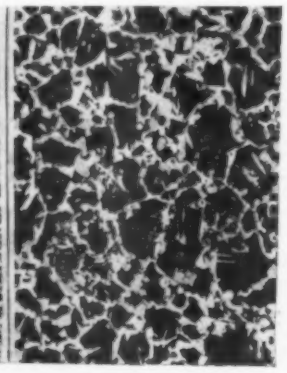
Spheroidising is a special form of annealing in which by prolonged heating of the steel at or below the lower critical or even slow cooling through that range and below it, the usual pearlite structure is completely destroyed, and instead of plates or granules of cementite interspersed with the associated ferrite the cementite is structurally free and isolated. This produces peculiar effects as in Damascening, and even induces specially low degrees of hardness in high carbon steels, since they have a continuous ferrite groundmass (Fig. 2), but generally in mild steels the result is a form of brittleness. The steel will stand quite well a severe and sudden deformation or bending, but even if cracking has not shown itself, the steel will not bend back again to position, and the reason is not far to seek when the structure reveals glass-hard cementite films around the ferrite crystal grains. Sometimes the formation takes the form of "atolls," as they were called by Howe,[1] although none of the illustrations he gives after holding at 685° C. for 24 hours showed the complete encircling of the internal ferrite of the pearlite grain by the divorced cementite, as seen in Fig. 3. It would be well to distinguish clearly between spheroidising and normalising, as they are or should be absolutely distinct, and yet we find records of steels[2] which have been so-called "normalised for 2,000 hours at 560° C.," and showing what is called a spheroidised structure, but which exactly conforms to the standard definition of granular pearlite.[3] Normalising is a comparatively short process for refining the grain from above the critical range, whilst spheroidising is a slow process conducted without grain refinement, and below the critical range.

1 Howe and Levy, "The Influence of Divorcing Annealing on the Mechanical Properties of Low Carbon Steels," *Trans. Amer. Inst. of Mining Eng.*, October, 1912.

0·4% *carbon, pearlite in ferrite.* × 100. FIG. 5.—HOT-ROLLED.



0·4% *carbon, pearlite in ferrite.* × 100. FIG. 6.—ANNEALED.



Patenting.

By far the most important heat-treatment which is imparted to steel wire is that covered by the generic term "patenting," introduced by Wm. Smith, of Warrington, to enable high carbon steel to be drawn many passes by "long-holing" without any intermediate treatment, or annealing, as would be needed were the steel not in this particular condition. Serious misconception is rife regarding the true nature of "patenting," and it has variously been termed "annealing," "normalising," and even "tempering," in spite of the authoritative pronouncement of Adam[4] that "it is not a true annealing, or even a normalising," as the "object of the process is the production of the particular structure—viz., large crystal size and sorbite." The structure resulting is really an overheated one, just short of the embrittling "burning" of the forging smith, and "the mechanism of the process consists in (*a*) raising the temperature of the metal steadily to a range depending upon the diameter of the wire concerned, *well above* the critical point of the steel involved; (*b*) secondly, the maintenance of this temperature for a period necessary to allow of complete diffusion of the carbon content, and the growth of the crystal grain size to the maximum allowable for the sectional area; and (*c*) then this is followed by a sufficiently rapid rate of cooling to bring about the retention of the dispersed carbide in the state of maximum sorbite."[5]

When the relative merits of time and temperature are so closely connected, it makes the study of the correct speeds and heats for the varying wire size and carbon content one of the most interesting problems in practical metallurgy, and constant personal watchfulness is required even with all the aids of pyrometry and metallography. The mode of operation varies very widely in different districts, but the underlying principle is in each case the same, which is to attain a sufficiently large grain size that it will stand the reduction of approximately 80% in drawing in the requisite number of drafts to give an adequate fibre length. If the grain size is too small to start with, then such an amount of reduction is very liable to produce the defects associated with "over-drawing" and on the other hand too large a grain size is equally deleterious for some purposes, and thus fails in heading and bending, as in a spoke wire.

Pearlitising.

The lack of the proper grain size or completeness of carbon dispersion may be caused by either too low temperature in the furnace, or too high a speed of traverse, thus allowing inadequate time for the requisite reaction to take place and the carbon to spread. The deficiency may not always show itself in the maximum tensile stress the wire will stand, but invariably lowers the toughness as expressed by the number of torsions the wire will undergo before fracture. Too slow cooling, even from the proper patenting temperature, is liable to cause trouble in the physical properties of the final wire, as in this case the structure is not completely sorbitic, and in places it is transformed into the distinctly laminated form of pearlite. This type of structure is definitely disadvantageous, as shown by numerous experimenters, and is obvious from consideration of the variable strength of the two constituents, pure ferrite, and plates of cementite, which part company when cold drawn.

2 Bailey and Roberts, "Testing of Materials for Service in High Temperature Steam Plant," *Proc. Inst. Mech. Eng.*, vol. 122, p. 209, February, 1932.

3 Howe and Sauveur, "The Nomenclature of the Microscopic Substances and Structures of Steel," *Proc. Inst. Assoc. for Testing Materials*, II., 7, 1912.

4 A. T. Adam, "Wire Drawing and Cold Working of Steel," H. F. and G. Witherby page 79. 1925.

5 J. S. G. Primrose, "Patenting of Steel," *Trans. Amer. Socy. for Steel Treating* vol. XII., p. 617. 1928.

To illustrate the progressively increased spreading of the carbon content of a medium-carbon steel, Figs. 5 to 8 show how the pearlite is arranged in normal hot-rolled rod, and the massing effect of ordinary softening annealing, the black areas in each case representing pearlite. With full patenting the amount of free ferrite is reduced to a minimum and the main mass is now sorbite, which even the highest power of magnification is unable to resolve, since it is an emulsion and completely devoid of the laminations of pearlite. As far as possible, the grain size is uniformly large, so that when insufficient time or temperature has been applied, and the resulting grain size is irregular, as in Fig. 8, this is not perfect patenting, and does not give the best result in the finished wire.

When the cold-drawing process has been applied to the two latter structures, the result is as shown in Figs. 9 and 10, all at the same magnification of 100 diameters. The perfectly patented steel when drawn shows the requisite good fibre length consistent with the requisite tensile strength and high proportion of elastic limit, whereas the imperfectly or "semi-patented" steel, when drawn reveals too much free ferrite, irregular fibre length, which is accompanied by much lower ratio of elastic limit to ultimate tensile stress, and moreover, the other physical properties are unreliable. Thus, both bends and twists

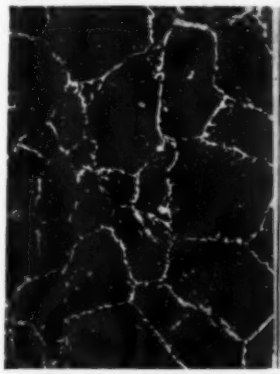


FIG. 7.—PATENTED. 0·4% *carbon, sorbite in large grains with small ferrite grain boundaries.* × 100.

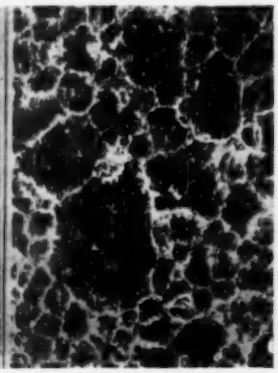


FIG. 8.—SEMI-PATENTED. 0·4% *carbon, irregular grained sorbite in excessive ferrite.* × 100.

are much below normal, and the life of the wire in actual service is much less than the perfectly patented structure with the optimum carbon spread.[6]

Lead Patenting.

When the mass effect of the wire or too slow cooling in any other way interferes with the rate of passage through the recalescence point, it shows the transformation of some of the sorbite into granular or even lamellar pearlite, and then the usual air cooling has to be replaced by some quicker method of cooling. This is adequately accomplished by using a bath of molten lead maintained at a minimum temperature of 500° C. for medium carbon steels, and, of course, higher for the higher carbons. The effect of this negative quenching is to almost entirely eliminate the free ferrite, and ensure complete sorbitising of the whole mass, with greatly improved qualities of toughness, and high resistance to fatigue and abrasion in the wire drawn from such a perfectly spread structure. It has been claimed[7] that structural differences between lead-cooled and air-cooled material are not apparent, but Figs. 11 and 12 adequately refute this statement, which has been confirmed by Adam. The lead bath patented wire of medium carbon content is entirely sorbitic, and free ferrite is absent, whereas in a similar steel wire air-cooled, the free ferrite is obvious, and so also is the lamellar pearlite. In actual service the springs made from former material stood up to severe service for over a year, whereas the pearlitised material failed within a few days of exactly similar work.

6 H. D. Lloyd, "Colliery Winding Ropes," "*Trans. South Wales Inst. of Eng.*, Dec. 1932.

7 R. Saxton, "Steel Wire Annealing," METALLURGIA, Vol. VII., No. 37, p. 25, November 1932.

FIG. 9.—DRAWN PATENTED. 0·4% *carbon, long fibre length sorbite with minimum ferrite.* × 100.

FIG. 10.—DRAWN SEMI-PATENTED. 0·4% *carbon, irregular fibre length sorbite in excessive ferrite.* × 100.

Water Patenting.

When low carbon steels are subjected to the patenting process, it is not possible to retain the small amount of carbon present in the maximum state if dispersion by either air or lead-bath cooling, and in this case the quenching is positive in cold water, instead of negative in hot lead for the higher carbons.[8] To attain the best results for such duty as upholstery springs, the wire must be heated to well over 950° C., and then slightly cooled before the material strikes the cold water, as it is possible even with low carbon steels to develop a diffused martensite, and thus cause definite embrittlement, as much as such drastic treatment would do to the higher carbons. The remarkable extent to which even a 0·1% carbon steel may have the carbon content spread by water patenting is shown in Fig. 4, which would readily pass for a steel with three times as much carbon as that actually present, were the heat-treatment not known. In this state the tensile strength of 50 tons per sq. in. is normally attained, and by drawing even without the increase due to ageing, this may be raised to 75 tons per sq. in., which is fairly noteworthy for so low a carbon steel.

Tempering.

The term "tempering" as applied to wire constitutes a reheating process applied after some form of quenching to harden, in order to diminish the brittleness set up. Full quenching might have produced some martensite of extreme brittleness, and the tempering is carried out at a sufficient temperature to ensure the "drawing" or letting down of this undesirable feature. Usually the result is a sorbitic structure, but even with great care in a lead bath it is possible to cut the time element too close, and leave some residual "troostite," which is an intermediate product in the decomposition of martensite. A slight amount of

8 Bedson and Primrose "Rod Rolling and Wire Drawing," *Journal W. of Scotland I. and S. Inst.* vol. XXXIV., p. 52, December, 1926.

0·45% *carbon, lamellar pearlite in drawn semi-patented spring wire.* × 1000.

FIG. 11.—PEARLITISED.

0·5% *carbon, completely sorbitic drawn spring wire.* × 500.

FIG. 12.—LEAD PATENTED.

this in springs might not prove harmful, but it has been shown[9] that at least one serious case of bridge wire failure in America was due to the inability of steel wire in such a structural state to withstand the stresses of a creeping load, and brittleness first developed surface cracks, and these rapidly developed in a way which could not have occurred in long fibre wire, and led to rapid destruction of the steel, which can only be attributed to the wrong type of microstructure, and one which needs the greatest care to detect.

Symposium on Steel Castings.

THIS volume contains ten extensive technical papers presented at a joint meeting of the American Foundrymen's Association and the American Society for Testing Materials in June last. The chief purpose of the publication is to provide the engineering profession with authoritative information on the properties of steel castings. The subject matter of the papers is very comprehensive, and embraces both carbon and alloy-steel castings. The first two papers are concerned primarily with steel casting production in the United States, and include a general survey of the industry and statistical data ; then follows an interesting contribution on the design of steel castings. The latter paper emphasises the importance of co-operation between designer and founder, and discusses extensively contraction and crystallisation phenomena under such headings as crystal formation, feeding of sections, effect of heat transmission, deep pockets, linear shrinkage, etc.

Purchase requirements for steel castings are discussed in a paper, and notes are given on physical properties in test-bars and in commercial castings. The authors explain design factors influencing test specimen results, chemical limitations for carbon steel, and summarise various specifications for carbon—and alloy—steel castings. A long and informative paper gives physical and mechanical properties of some well-known cast steels. This presents a comprehensive correlation from many sources of data on the more frequently ascertained physical properties, as well as on magnetic endurance, creep, and other properties. Data cover the various carbon and alloy steels which are used for various types of castings.

The representative properties of cast medium pearlitic steels are reviewed. As a rule, pearlitic steels contain a small percentage of some alloying element, and the author discusses pearlitic carbon and low-alloy steels, containing various percentages of molybdenum, vanadium, chromium, and nickel-chromium steels for high temperatures, and pearlitic manganese steels. The results given in this paper were contributed by foundries regularly producing the steels described, and are more informative than the results of heats made for experimental purposes. A valuable paper on castings of corrosion-resistant steels is included, which gives considerable data on the principal classes of these alloys, covering physical properties at room and elevated temperatures, machining and welding behaviour, coefficient of thermal expansion, melting point, maximum temperature for safe use, etc. This contribution also includes a discussion of general considerations affecting alloy selection, and outlines the features of the several alloys. Other papers embrace austenitic manganese steel castings, problems and practices in the heat-treatment of steel castings, and fusion welding steel castings.

The value of these papers has been considerably increased by the publication in this volume of the discussion which resulted from their presentation ; further, diagrams, charts, and tables have been used by the authors to enable a quick and clear presentation of the data. The Symposium involves 254 pages, and it is bound in a heavy paper cover. Copies may be obtained from the American Society for Testing Materials, 1315, Spruce Street, Philadelphia, or the American Foundrymen's Association, 222, W. Adams Street, Chicago, U.S.A., at $1.00 each.

9 E. E. Thum, "Brittleness of Heat-treated Wire under Slowly Creeping Stress, *Metal Progress*, vol. 22, p. 43, September, 1932.

CHALIABINSK TRACTOR WORKS.

INDUSTRIAL development is making rapid progress in Russia, and this year will determine the extent to which these developments harmonise with the general well-being of this country and its people. One of the largest of the undertakings in this development is now nearing completion. This is the Chaliabinsk tractor works, which, when opened, will provide the Soviet Union with the largest tractor works in the world. The official opening of this plant has been planned for May 15, 1933, and although it will probably be some considerable time after that before production will be near its maximum, efforts will certainly be made to produce tractors on a vast scale as quickly as possible.

Before definite plans were prepared for the construction of this plant Soviet engineers spent considerable time in other countries, notably in Detroit, U.S.A., where they remained over a year (1929–1930), making a special study of production methods and consulting with American engineers who were specialists in the caterpillar type of tractor the works at Chaliabinsk is to produce.

Some of the departments in these works are of interest, particularly the forge press department, which is claimed to be not only the largest in the U.S.S.R., but in all Europe. It consists of three sections—the forge, hammer, and press shops. The production capacity of the department is 90,000 tons of forgings per year. Associated with this building is the heat-treatment department. This is designed for dealing with castings, forgings, stamped products and tools. It is equipped with eight large gas furnaces, several smaller heat-treatment furnaces, and a very large electric furnace.

Chaliabinsk is situated on the Asiatic side of the Urals, on the border of the Ural, Kasakhistan, and Siberian provinces. It was chosen as a suitable site for industrial development because it is in the heart of one of the biggest wheat growing districts in the Union, and it is this district primarily to which the works will supply tractors. The district has the additional advantage of being rich in raw materials. For instance, the plant will obtain the necessary iron from Magnitogorsk ; coal is found in the district, while steel and an ample supply of many other materials necessary will be obtained from the Slatanst metallurgical works, and electrical power will be supplied by the Chaliaberestroi electric station.

This new tractor plant working at full capacity will have a yearly output of 40,000 caterpillar tractors of 60 h.p. each. Bearing in mind that the only tractor works with which output comparisons can be made has a capacity of 20,000 tractors, the phenomenal output of these new works will be appreciated. Including those at Chaliabinsk there will be three tractor plants in the Soviet Union : Stalingrad, Charkow, and Chaliabinsk. The works at Red Putilow, where many tractors have been produced, will in future concentrate on the production of motor-cars and trucks.

Many other industrial works will centre round this tractor plant, covering a wide range of products, but chiefly machinery, chemicals, etc. In a few years' time Chaliabinsk will be the centre of a large industrial population, as the tractor plant alone will employ about 20,000 workpeople in addition to 3,700 Russian and about 200 foreign specialists. In fact, this will eventually be one of Russia's largest industrial centres, as not only are model houses being built for accommodating 150,000 people, but new railways will connect Chaliabinsk with the rest of the district, such as the Chaliabinsk-Murmansk and the Chaliabinsk-Aktubuit lines.

The planned cost of these works ranges about 300 million roubles. The latest machinery is being installed, over a million pounds having been spent on British, German, and American machinery, while Soviet machinery is also being installed. From many points of view this plant will be on colossal lines, and every effort is being made to adopt the most modern practice in production operations.

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The British Journal of Metals

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1932-1933.

THERE will have been few regrets at the passing of 1932. It has been a difficult year for everyone, due largely to the trade depression which, if anything, was more acute than during the preceding year. The resulting unemployment pressed heavily upon the nation and interfered with the whole social fabric, which created a feeling of uncertainty that reacted on industrial development. Despite the disappointments of the year the abandonment of Free Trade gives 1932 an historical significance. This fundamental change was only made after a political fight which lasted many years. In view of the economic stress, it was necessary to adopt a protective policy, but no immediate benefit accrued because the action taken was anticipated and this country became a dumping ground for a wide range of commodities. In some instances stocks of foreign products stored in this country before the Import Duties Act became operative were so much beyond our usual rate of consumption that they are not yet entirely exhausted.

The success of the tariff policy adopted by this country is still somewhat problematic, but there seems little doubt that it has had beneficial influences on some industries, and the slight improvement in the iron and steel industry, which is gradually becoming apparent, is claimed as a direct result, and is tending to restore this basic industry to a position commensurate with its importance.

While this policy is having considerable influence in helping industry to consolidate the home market, and has caused many foreign firms to make arrangements for the manufacture of their specialities in this country, efforts have been made to maintain markets overseas and to secure new markets. It is appreciated that we cannot live in isolation; we must export because we are forced to import, and it is essential that these should balance as far as possible.

The agreements entered into as a result of the Ottawa Conference have an important significance, since they are likely to increase trade between the various nations of the British Commonwealth and foster interdependence between them. Empire trading has great possibilities, the potentialities of which are not fully realised, but while every effort should be made to improve trade with the Dominions, world markets are just as essential for our ever-increasing range of products.

It is our opinion that these trading agreements based on tariff modifications only touch the fringe of the difficulties which are preventing a more rapid restoration of world trade. Increasing tariffs simply constitute a form of economic war, and do not foster trade. Instead of seeking the lowest common denominator by which nations can enter into satisfactory trading operations, the tendency has been to raise the protective wall higher with the object of keeping goods out. Yet those countries which are making the biggest noise against imports are all desperately anxious to export their own products. Instead of entering into separate agreements, let Britain make a stand for lower tariffs and prepare a schedule giving terms under which she is prepared to trade with any nation willing to reciprocate. This, we believe, would have a greater influence upon the freer movement of manufactures and products between countries, and, particularly at this time, when indications point to a slight recovery, would give that impetus industry so much needs.

Although high tariffs are proving to be an effective barrier to adequate trade development, they do not provide the only factor operating against recovery. One of the main problems is yet unsolved, and the prospects of an immediate solution are very remote. We allude to war debts, with which world trade is intimately linked. Unless an amicable solution is found to this thorny problem recovery in world trade, to any appreciable extent, is impossible. What possible value can there be in discussing economic problems at the forthcoming World's Economic Conference if, as the conditions stipulate, the United States excludes tariffs, reparations, and war debts from the Conference agenda? These are the problems that most need solving, as, however much conditions may favour world recovery, there can be no satisfactory progress until they are finally settled. Such a settlement would be effective in freeing the monetary position, in which sterling seems to have become a more stable measure of value than gold.

It seems strange that though France and America have continued to purchase gold on a gold standard basis, neither country seems to have benefited from the monopoly. The United States in particular is facing many perplexing problems that threaten her with disaster. Meanwhile, forty-five nations are now off the gold standard, thirty-four of these have officially abandoned its operation, and eleven have done so in effect by restricting foreign exchange. Re-establishing an international monetary standard was discussed by the expert committee at Geneva, which is charged with the task of preparing the ground for the World's Economic Conference, and an important statement regarding British monetary policy was made by Sir Frederick Leith-Ross. Britain, he declared, is willing and anxious to co-operate in re-establishing an international monetary standard, but she is not prepared to link the £ to gold again unless certain conditions are satisfied. It seems perfectly clear that we definitely want and hope to see our own and all the rest of the world's currencies once more on a stable footing of exchange; in justice to all concerned, however, there must be a settlement of war debts, an agreement on tariffs, and a definite understanding regarding the working of a restored gold standard.

There are thus several problems thrust upon the new year, all of which have a direct influence on the recovery of normal trade operations, and their satisfactory solution is keenly awaited by a world endeavouring to free itself from the octopus-like hold of adversity. These problems are political rather than industrial, and they present opportunities for Britain to give a lead to their solution, so that the more hopeful signs of trade recovery now manifest may proceed unchecked towards fulfilment. Should successful action of this nature be taken, historians may well be able to record this year as the year Great Britain once more took the turn towards progress and prosperity after more than a decade of difficulty and vaccilation. There is abundant evidence that in a reeling world British political, financial, and social institutions have proved themselves more stable and yet more adaptable to the changing times than those of any other country. Changes which in other countries are being accompanied by confusion and violence, are taking place here almost imperceptibly by slow, sure, and peaceful processes, the credit for which is largely due to the commonsense and steadfastness of its people.

MAN AND MACHINE.

CONSIDERABLE interest has been aroused in America by a body of economists and engineers known as "technocrats," who have been studying what they term "technocracy" for a number of years. Apparently the result of these studies has convinced them that the price system in ordinary commercial enterprises has broken down and must be replaced by something better. The scientist and the engineer, by the rapid development of machinery, are responsible for changes of the utmost importance, and these changes have afflicted every civilised country with stagnation and distress. Machinery, according to this group, has made such progress that the adult population of America need only work four hours per day and four days per week to supply all their material wants. It is to this fact that they attribute the cause of the nation's difficulties. They claim that all the usable wants of the world could, under efficient management, be produced in a fraction of what is now considered to be the normal working day.

Few will contest this statement, but the distress in civilised countries is largely due to the fact that while production has been speeded-up at a remarkable rate a country cannot sell sufficient of its own products to enable it to buy what it needs from others. Machinery has certainly shown immense possibilities, but there are still countless people without what we have come to regard as the bare necessities of life. Actually, the consumer demand is not being met, because, cheap as machine-made goods are, there is a scarcity of money.

Research has in many instances raised the capacity for output a thousandfold, and in practically everything humanity should be richer. All that people need can be made in such quantities that nobody should go short, but there is a lack of purchasers; invention and organisation are supplanting labour and reducing purchasing power. Even with rapid improvement of trade a large proportion of those now unemployed will never be reabsorbed into industry under present conditions. Mechanical development proceeds automatically, tending to increase the numbers of unemployed and incidentally reducing the potential purchasers of the commodities produced. This encourages an increasing gulf between plenty and poverty.

The technocrats state that the energy output per man has increased to such an extent that the financial and industrial organisation is at death's grips with the machine, and the latter is apparently winning. They assert that a social wreck is inevitable unless the process is halted. They suggest that production and distribution should be committed to an expert authority which will supersede the industrialist, the banker and the politician. Money, as we know it, is to disappear, but the method of trading is somewhat obscure. The broad aim, however, seems to be to secure full advantages from modern machinery for the greatest number of people, that all should participate in the boons that accrue.

We cannot say that this technocracy gives us more confidence in the ultimate satisfactory solution of what must be regarded as a riddle, but it is gratifying to know that technologists of repute are giving the subject very earnest thought. No right-thinking person can be satisfied with a situation in which higher scientific attainment means utter ruin for thousands of people. Machinery must be used to the benefit of mankind, to uplift the human race, and its development should be guided with that end in view. All thought and experiment that assists towards a solution of the problems machinery has involved should be welcomed. This group of technologists do at least realise the inevitability of obsolescence, and while it may not be necessary to revolutionise our conceptions of trade, some permanent plan should be prepared which will render all energy effective for a more limited time and overcome the present disability of the machine in dispensing with human assistance.

FORTHCOMING MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.

Jan. 27. "Canadian Methods of Handling and Storing Grain," by H. H. Broughton, M.I.Mech.E.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Jan. 27. "Modern Ship repairing," by J. Patton.
Feb. 3. "Destroyer Forms," by J. L. Scott.
Feb. 10. "Approximating E.H.P.: Notes of Amendments to Data given in 1927 Paper," by A. L. Ayre, O.B.E.

THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.

Feb. 14. "Manufacture of High-quality Cast Iron in the Rotary Pulverised-fuel Furnace," by P. M. Macnair, B.Sc., Ph.D.

INSTITUTION OF AUTOMOBILE ENGINEERS.

Jan. 18. "Electrical Equipment for Automobiles," by E. A. Watson, at Metropolé Hotel, Leeds.
Jan. 17. "Alloy Cast Irons in Automobile Construction," by Dr. A. B. Everest, at Victoria Hotel, Wolverhampton.

THE INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Jan. 19. "Moulding Sands," by J. G. A. Skerl, D.Sc.
Feb. 2. "Refractories in Metallurgical Industries," by A. T. Green.

LONDON SECTION.

Feb. 8. Open discussion on "Non-ferrous Metals in the Food Industry." (Joint meeting with the Food Group of the Society of Chemical Industry.)

NORTH-EAST COAST SECTION.

Feb. 14. "Further Experiments on Extrusion," by C. E. Pearson, M.Met.

SCOTTISH SECTION.

Feb. 13. "Modern Light Alloys, with Particular Reference to Corrosion," by Leslie Aitchison, D.Met., B.Sc.

SHEFFIELD SECTION.

Feb. 10. "Soft Solders and Fluxes," by O. F. Hudson, D.Sc.

SWANSEA SECTION.

Feb. 14. "Platinum Metals," by R. H. Atkinson, M.A.

INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

Feb. 2. "The Open-hearth Process for Steel Castings Production," by W. H. Thompson.

EAST MIDLANDS BRANCH.

Jan. 28. "Cupola Practice," by John Cameron, J.P., at Derby.

LINCOLNSHIRE SECTION.

Feb. 4. "Shrinkage and Porosity in Grey Cast Iron," by P. A. Russell, B.Sc.

LANCASHIRE BRANCH.

Feb. 4. Annual Dinner.

BURNLEY SECTION.

Feb. 9. "Making a Cloth Roller for Printing Machine," by W. H. Meadowcroft.

PRESTON SECTION.

Feb. 8. "Coke; its Properties and Uses," by D. V. Hollingworth, F.I.C., F.C.S.

LONDON BRANCH.

Feb. 9. "Mechanical Handling in the Foundry," by A. W. G. Bagshawe.

MIDDLESBROUGH BRANCH.

Jan. 27. "The Core Shop Mechanised," by G. E. France.
Feb. 10. "The Wear of Cast Iron," by F. K. Neath, B.Sc.

NEWCASTLE-UPON-TYNE BRANCH.

Jan. 28. Competitors' Papers submitted by Members and Apprentices.

SCOTTISH BRANCH.

Jan. 28. "Sand Testing in the Foundry," by W. Y. Buchanan. (At Edinburgh.)
Feb. 4. "Modern Aluminium Foundry Metallurgy," by N. F. Budgen, Ph.D., M.Sc.

FALKIRK SECTION.

Jan. 21. "Furnace Linings," by J. F. Hyslop.

SHEFFIELD BRANCH.

Jan. 20. "Cupola Control: its Progress and Value in the Iron Foundry," by E. Wharton.
Feb. 17. "Mechanised Core Shops," by H. F. Coggon.

WEST RIDING OF YORKSHIRE BRANCH.

Feb. 11. "Cause and Effect in the Bronze Foundry," by F. W. Rowe, B.Sc.

THE INSTITUTE OF MARINE ENGINEERS.

Feb. 14. "The Modern Trend in Marine Steam Practice," by John Neill, B.Sc.

Correspondence.

The Editor, METALLURGIA.

January 6, 1933.

Sir,—In METALLURGIA of November, 1932, you published an article under the title of "Surface Hardening Scientifically" in which arguments were set forth purporting to demonstrate the advantage of surface hardening by mechanical means over surface hardening by hand operation of the hardening flame. We are of opinion that the comparison made was not a fair one, particularly as regards the quality of work that may be done by the hand-operation method, and we should be glad, therefore, if you would allow space for the following remarks in a future issue.

The method of hardening in question consists in heating the steel surface locally to the proper hardening temperature by a moving oxy-acetylene flame which is immediately followed by a jet of water. This process, as is well known, was devised by Mr. L. Sumpter, of Vickers, Ltd., many years ago,* and is essentially the same whether the flame is operated by hand or traversed over the face of the gear by mechanical means as in the machine referred to in the previous article. Any advantage of one method over the other, therefore, is merely a matter of technique or convenience, and is not fundamental. If ideal conditions could be secured equally good results would be obtained by either mechanical or hand control.

Contrary to the general impression conveyed by Mr. Shorter's article, hand operation is in fact very satisfactory. This is borne out by the experience of many traction engineers, and during the last fifteen years we ourselves have manufactured and supplied to our customers some thousands of surface-hardened traction gears which have been hardened by hand and which have given extremely good service.

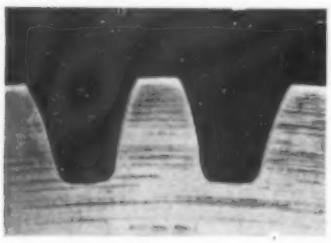


Fig. 2.—End view of teeth.

After many years of heavy service these gears show little wear by abrasion, and the two illustrations (Figs. 1 and 2) show a typical wheel after over nine years' service on a tramway undertaking in this country. Fig. 1 shows the general appearance of the tooth profile, and it will be noticed that the wear is even across the face. Fig. 2 shows an end view of the teeth on the same wheel, and again emphasises the absence of wear.

Whilst we agree that the examples of hand-hardening shown in Fig. 5 of Mr. Shorter's article are very inferior, and could not be expected to behave satisfactorily in service, we wish to state emphatically that the examples shown are much below the standard of results that should be and are obtained in everyday practice given normally skilled operation. On the other hand, we have examined mechanically surface-hardened teeth and found the hardening to be far removed from the uniformity illustrated by Mr. Shorter in his article.

Mr. Shorter's article is also somewhat misleading in regard to the shape of the hardened zone. The straight-line motion of the hardening flame along the length of the tooth advocated by Mr. Shorter is naturally the most convenient for mechanical operation, and could equally well be adopted for hand operation. Actually, however, there are cogent reasons in favour of the oscillating flame, and although the latter method does not give maximum hardness over quite the full working face of the teeth, this in good practice is not of importance.

The markings in Figs. 1 and 2 of Mr. Shorter's article

*Patents Nos. 5588/1910 and 16643/1913.

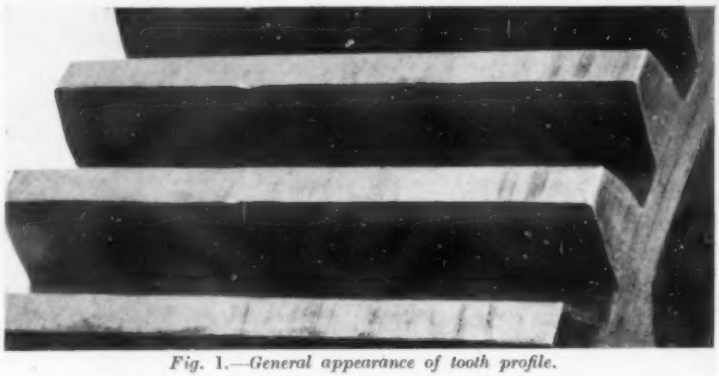


Fig. 1.—General appearance of tooth profile.

are, of course, the result of etching, and in themselves bear no direct relation to the internal stresses produced on hardening. It is impossible from a comparison of the two photographs to say which tooth contains the highest hardening stresses.

In our opinion it remains to be demonstrated that mechanical surface-hardening of gear teeth has yet reached the stage of development where it can compete on the score of quality or economy with intelligent hand operation. We reiterate that the surface-hardened gear, hardened by hand under proper conditions, has been proved by long experience to be eminently satisfactory, and we regret that Mr. Shorter's article is misleading in implying otherwise.—Yours, etc.,

(Signed) G. H. FLETCHER,
Chief Engineer and Manager, Metropolitan-Vickers Elec. Co., Ltd., Attercliffe Common Works, Sheffield.

Heat Treating and Forging Some Light Alloys.

[Further to the correspondence published in the December issue of this journal regarding questions of grain growth during prolonged heating, we publish another communication which was too late for inclusion in the last issue.—EDITOR.]

December 20, 1932.

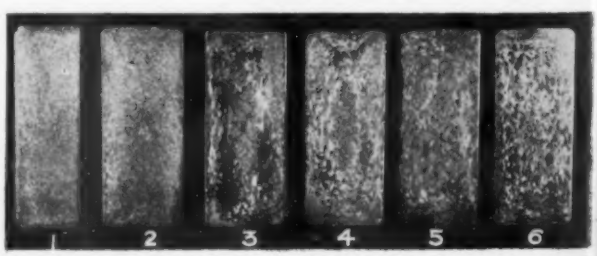
The Editor, METALLURGIA.

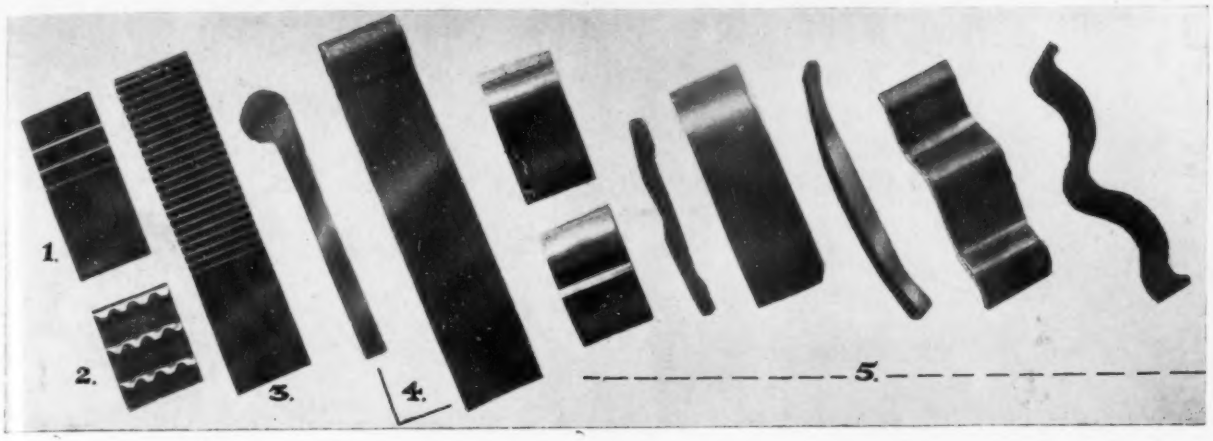
Dear Sir,—The first letter by Mr. Tullis dealt with grain growth experienced with soaking after the cast ingot had been subjected to work, and I am convinced that no degasifying process will affect this.

In his letter of December 12, however, he deals with metal that is being cast only, and I would rather call this crystal formation than crystal growth. I am quite willing to agree that there are many processes which will refine the metal during casting—for instance, with aluminium alloys the addition of small percentages of titanium or of boron, but even metal so treated, which has remarkably fine grain in the cast ingot condition, will, if plastic deformation takes place at certain temperatures and time, exhibit the grain growth phenomena referred to in my paper, as is demonstrated by various photographs taken of material which in the cast condition had exceptionally fine grain size. (See photographs enclosed).—Yours, etc.,

High Duty Alloys, Ltd., Slough. W. C. DEVEREUX.

Effect of temperature on crystal growth: (1) *1 hour, 530° C. quenched;* (2) *2 hours, 490°-500° C. quenched;* (3) *12 hours, 490°-500° C. quenched;* (4) *12 hours, 490°-500° C. quenched and aged;* (5) *24 hours, 490°-500° C. quenched;* (6) *24 hours, 490°-500° C. quenched and aged.*





Typical Examples of Sections and outstanding features required.
1. Matchett Blade Section.—High Finish. 2. Treadplate Section.—Deep Serrations. 3. Serrated Section.—Extreme Accuracy of Grooving. 4. Bulb Hinge Section.—Accuracy of Shape. 5. Bumper Bar Sections.—High Finish.

High Quality Finish on Rolled Sections

Obtaining a superior finish on rolled steel sections slows down the speed of production, but since a high finish reduces the number of operations in converting the rolled sections into manufactured articles. the increased cost is justified and ensures economical advantages to the user. Reference is made to the finish on sections that compare favourably with machined surfaces.

THE demand for increased accuracy and improved quality of product is fully appreciated in the rolling mill, and developments in plant and equipment, as well as improved technique, are responsible for much of the progress achieved during recent years. Each branch of the industry has benefited from a close study of the problems associated with the variation in the character of the materials rolled, and substantial improvements have been made, not only in regard to accuracy and quality, but also in the speed of production. Speed of production is, of course, a relative term, and depends to a considerable extent on the degree of finish required and the accuracy of the rolled section desired. When large output is of primary importance quality of finish must be sacrificed. Generally, efforts are made to obtain the best possible finish consistent with the speed of production.

The greatest problem in rolling steel is to limit the effects of oxidation, which has an important influence on the quality of the materials. This problem enters into all rolling operations, because hot-rolling predominates, and is, in fact, indispensable. Although furnaces have been designed and constructed that successfully reduce oxidation while the material is being heated, no method yet devised has been successful in preventing oxidation when the material is passing through the various stands of the mill. To overcome this, precautions must be taken to remove the scale formed in order that the quality of finish on the rolled sections will satisfy requirements, and, invariably, its removal involves a slowing-down of the rolling operation. Thus, in practice, conditions influence production and high quality of finish may be sacrificed to obtain a large output. On the other hand, when finish is of primary importance the speed of production will be guided by the degree of finish desired, and this in turn will be governed by the use to which the rolled section is applied; certainly

Fig. 1.—Rolled sections on the cooling bed shortly after rolling.

Fig. 2.—12-in. double-duo mill in which the sections were rolled.

some sacrifice must be made according to whether high finish or output is of greater importance.

Speed in production has an important economic influence on the method adopted, and when large outputs are required special advantages are claimed for continuous and semi-continuous mills. In these mills the material is rolled so rapidly that oxidation is claimed to be reduced to a minimum, and as the reduction in area is regular, little power is required to drive; the operation is practically automatic, very little skilled labour is necessary, and the great length of material rolled reduces the waste in crop ends to a minimum. These are distinct advantages, since they reduce the cost of production, but only in cases when the output of a section warrants the adoption of such methods.

When a wide range of sections is called for, and each is required in relatively small quantities, the question arises which type of mill will give the most consistent good results over the longest period of service, with a minimum cost of upkeep. Opinions differ on this point, but for sections many prefer the Double Duo, which is capable of rolling material well within the specified limits required, in regard to time, finish, and accuracy. Because of the smaller quantities required of a given section, operating costs are higher, but, as a rule, more attention can be given to the degree of finish produced on the rolled material.

When less attention is given to the removal of scale during the time of rolling, it becomes associated with the section, and while, for certain classes of work, the inferior finish which is produced may suffice, any further operations to which the surface may be subjected, as in the case of nickel or chromium plating, will necessitate the removal of this oxide. Generally, the parts are pickled to remove the oxide, and in consequence the surfaces become pitted and quite unfitted for plating until suitably ground and buffed. Thus, although the cost of the rolled section may be low, the increased work necessary to prepare it for its final finish may make its use very costly. With proper care in rolling, however, it is possible to produce a finish that dispenses with the need for pickling, reducing the operations preparatory to plating to buffing only. Under these conditions the quality of finish has greater economical significance than the speed of output, since it enables at least one subsequent operation to be omitted.

Various methods are adopted to prevent scale being rolled into the surface of the material when a high degree of

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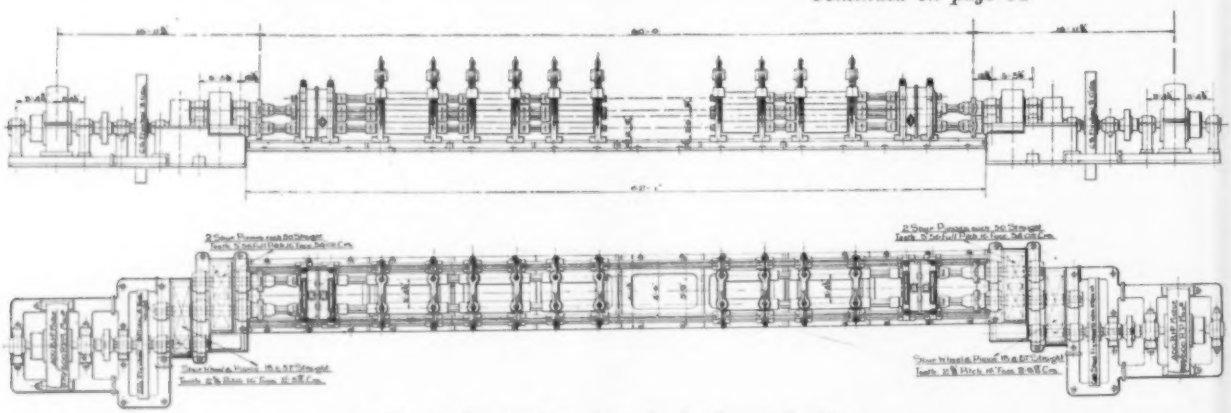


Fig. 3.—Plan and elevation, showing layout of mill.

Fig. 4.—Drawing the billets from a recuperator furnace for rolling.

Electricity in Heating and Melting of Metals

By A. G. Robiette, B.Sc., (Met.)

Developments in metallurgical processes have shown the need for accuracy and control of heating and melting operations in order to meet the more exacting demands of the engineer. In this article special claims are made for the use of electricity to meet these requirements.

WE have witnessed during the past few years a truly remarkable advance in metallurgical knowledge which has brought into being a new range of materials of construction, created to meet the more exacting demands of modern engineering. This advance has emphasised the need for greater accuracy and control in melting and heat-treatment operations.

Not many years ago coal and coke held a monopoly as the heating medium for metallurgical processes. For the finer metallurgical operations the solid fuels have recently been deposed from their position of supremacy by the more flexible and adaptable fuels—oil, gas, pulverised fuel, and electricity. These latter fuels, in spite of their increased cost, have successfully withstood competition with coal and coke. It is obvious, therefore, that the too prevalent fallacy of comparing fuels on a B.th.u. basis gives an erroneous value of their relative economies.

Fig. 1 has been compiled to show the comparative heating values of commercial fuels and electricity and to illustrate the apparent overwhelming advantage of solid fuels. The efficiency of the application of heat has, however, also to be brought into consideration, and when this is done the advantage moves towards the range of higher priced fuels. To take a concrete example, consider the application of the crucible furnace for the melting of brass or steel, and compare this now obsolescent mode of heating with the Ajax-Wyatt and coreless induction furnaces. Crucible furnaces vary considerably, but it is doubtful whether the efficiency ever exceeds 5%, and sometimes it is as low as 2·5%. On the other hand, the coreless induction furnace, which is rapidly supplanting the crucible steel process, gives an efficiency of 60–65%, while the Ajax-Wyatt furnace, which is almost universally used for melting wrought brass, gives an efficiency of 85%.

The following figures have been collated to show the useful B.th.u.'s bought for 1d. when using any of these furnaces :—

				Useful B.th.u.'s Bought for 1d.
Crucible furnace	.. Coke at 16s. per ton; 12,900 B.th.u.'s/lb.	.. 5%	efficiency ..	7,500
Ajax-Wyatt furnace.	.. Electricity, 0·4d.	.. 85%	„ ..	7,450
Coreless Induction furnace.	.. Electricity, 0·4d.	.. 65%	„ ..	5,540

It will be seen that in the case of the low-frequency furnace fuel and electricity costs are equal, while there is no very appreciable advantage for coke as compared with electricity in steel-melting furnaces. It must be emphasised, of course, that this comparison neglects all consideration of refractory costs, metal losses, labour charges, etc., which when taken into account will show a very large margin in favour of electricity.

This brings us to the relation between the cost of process heating and the overall cost of the product, which in many cases is the governing factor in the choice of a heating medium. It is generally accepted that electricity, if properly applied, is the source of heat most amenable to accurate control, both in regard to degree and distribution. Moreover, the atmosphere, being independent of the heating agent, may be adjusted with infinite elasticity to suit the needs of the process. These factors generally make for improved quality, fewer rejects, lower metal losses, and improved labour efficiency. In some processes these advantages when capitalised would not justify the additional outlay and running costs, while in other operations, where the cost of heating is only a fraction of the total cost of processing, electricity shows untold economies. It is, therefore, essential to consider each case on its merits before recommending or condemning the adoption of electric melting or heating.

Melting Practice.

The arc furnace leaped into prominence during the war, when it was essential to find an appliance for remelting for ordnance purposes the vast quantity of alloy steel scrap which was being produced. The acid-lined arc furnace was the only equipment capable of achieving this object without the loss of expensive alloying elements. It was also found possible to make a very high-grade steel from low-grade scrap, which was important from the point of view of increasing the range of raw materials. Desulphurising conditions unparalleled in any other type of furnace are obtainable, due to the highly calcareous slag which may be carried under the intense heat of the arc. The steel produced, though better in every way than open-hearth steel, does not always attain the standard of crucible steel.

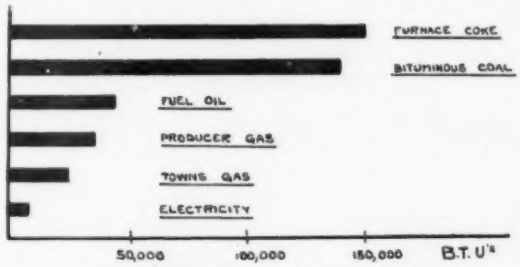


Fig. 1.—Relative cost of industrial fuels.

In recent years the arc furnace has found a wide application for the melting and superheating of special high-duty irons. Though more expensive than the cupola or pulverised fuel firing, it is being used for making synthetic irons from steel scrap, with the addition of the necessary carbon and other alloys. The composition is under more accurate control and refractory troubles are perhaps not so serious as in pulverised fuel melting.

It has found more favour, however, for refining and superheating liquid metal which is duplexed from a cupola or blast-furnace. The sulphur, phosphorus, and carbon can be reduced to any desired extent, alloy additions made in the furnace without loss, and the metal superheated to any required temperature. These advantages more than repay the small power consumption, which amounts to approximately 6s. 8d. per ton (200 units at ·4d.).

The coreless induction furnace is a post-war development, and is essentially a crucible furnace with an almost unlimited capacity. For the melting of cobalt magnet steels, high-grade tool steels, complex heat-resisting steels, austenitic nickel-chromium corrosion resisting steels, high-speed steels, nickel-iron and nickel-chromium alloys, it has within the past five years become the standard melting equipment. It has been shown that on a cost of fuel basis alone there is not a wide margin of disadvantage, which is easily made

up by the savings in refractory crucibles alone when a fritted lining is used. Labour costs are almost halved, lost heats are eliminated, and losses in alloying elements minimised—factors which are sufficient to justify its installation on these grounds alone. It has also solved the serious problem of remelting special alloy steel scrap without loss of cobalt, chromium, and other metals, and without pick-up of carbon, which is so deleterious to nickel-chromium alloys, stainless steels, and high permeability nickel-iron alloys.

The rapid circulation brought about by electrical effects enables deoxidation and removal of inclusions to be effected to such a remarkable extent that an over-oxidised steel can be clarified by treatment in this furnace and made to compare with the highest grade of crucible steel. This is due to the products of deoxidation being brought successively into contact with a fluid slag by the circulating motion of the metal, which also produces perfect homogeneity. A test was carried out to prove the efficacy of this mixing action. Tungsten was placed in the bottom of a furnace and a steel charge poured on top. When cast into ingots the steel showed on analysis no difference in tungsten content when samples were taken from top and bottom portions of the ingot.

The ideal conditions which obtain for clarifying steel of the products of deoxidation are rapidly being taken advantage of for high-grade carbon steels. Installations have been and are being constructed for working a duplex process, the coreless induction furnace being only used for "conditioning" the metal before teeming.

It may be added that for the melting of ordinary "tonnage" steel the additional cost is not commensurate with the advantages to be gained. Here a low-priced product is being treated, and any additional improvement in quality will not command a higher price. The day is not yet in sight when electricity will enter into competition with other fuels in this field.

Of the Ajax-Wyatt or normal frequency induction furnace little need be said except that approximately 90% of the world's wrought brass requirements are being melted in this type of furnace, which is undoubtedly the most efficient melting furnace yet devised. For the melting of other metals, refractory troubles are being gradually overcome, and this furnace is now being used for nickel-silver, zinc, cupro-nickel, and copper.

As a result of recent research, it has been established that melting conditions are mainly responsible for the quality of aluminium and aluminium rich castings and ingots. Gaseous inclusions which give rise to pinholes are caused by dissolved gases which aluminium readily absorbs from the furnace atmosphere. Aluminium is particularly sensitive to water vapour, which is always formed as a product of combustion and which will penetrate the densest refractory crucible. Electric melting in resistance-heated furnaces has done much to produce sounder aluminium ingots and castings, and its application is rapidly spreading. In this case improved quality alone will stand the added cost of electric melting.

Heat-Treatment.

For some processes electric heating shows a saving on a direct cost of fuel and electricity basis alone. This is a consequence of the very high efficiency obtainable by the liberal use of heat-insulating material. It will perhaps be surprising to note that in general it costs less to maintain an efficient electric furnace at temperature than a gas furnace of the same size (but not of a recuperative type). For instance, to maintain temperature at 800° C., a modern electric furnace, 36 in. long × 20 in. wide × 16 in. high would consume approximately 4·25 units per hour (= 3·2d. at 0·75d. per kw.-hr.), while a gas furnace of the same dimensions would require 235 cub. ft. per hour (= 5·6d. at 2s. per 1,000 cub. ft.). It is evident, therefore, that for processes which necessitate long soaking periods, such as carburising and nitriding, electric furnaces are definitely economical.

Generally speaking, electric furnaces are more advantageously operated continuously, as it costs more and takes longer to heat up a furnace by electricity than by other fuels. It must not be concluded that it is entirely unsuited to intermittent working. On the other hand, for operations such as tool hardening, where the furnace has to be on stand-by for considerable periods and ready always when occasion demands, it is definitely advantageous, due to the very low input required to maintain the furnace at temperature.

The above considerations only cover a portion of the field of application of electric heating in metallurgical processes. In other applications electricity labours under the disadvantage of a higher heating cost, yet its adoption is often justified.

It is almost universally admitted that even distribution of temperature and accurate control are more readily attained with electric heating. This will inevitably result in improved quality and elimination of wastage. On the other hand, for fine heat-treatment operations the cost of heating is an almost negligible proportion of the ultimate cost of the product. For hardening and tempering machine parts, for the finish annealing of non-ferrous strip and wire, for the heat-treatment of aluminium and aluminium alloy products, etc., it is doubtful whether the cost of heating ever exceeds 1–1·5% of the overall cost. This being so, any resulting improvement in consistency of quality which connotes elimination of spoilage will not only pay for the small additional cost of electric heating, but show an appreciable return for expenditure. Any comparison of the relative merits of different fuels or electricity must be made on the basis of cost per unit of given quality.

Experience of many hundreds of electric furnace installations has shown that electric heating possesses an economic value productive of results difficult to duplicate with combustion heating, and showing advantages to which it is difficult to assess a monetary value.

These benefits include cleanliness and comfort in operating conditions due to absence of freely radiated heat and products of combustion; freedom from noise; facility of location of plant, which may be situated in the most advantageous position from the point of view of production, and where it would be inconvenient to run pipe-lines or flues; possibility of working the furnace automatically with a time switch or programme recorder, no night labour being required; improvement in the load and power factor of the works, enabling current to be purchased at lower rates; independence of atmosphere on the source of heat; and many other advantages peculiar to different types of installation.

Another consideration in fuel-fired furnaces is the life of refractory walls. With electric heating rarely does any part of the furnace exceed the working temperature by more than 100° C. Moreover, by the use of heat-insulating material the temperature gradient through the refractory wall (which is generally approximately half the thickness of that used in fuel-fired furnaces) is very small, with the result that expansion and other stresses are less severe. Under these conditions the life of refractory material is almost indefinite.

It is sometimes said that this low temperature difference between the resistor elements and the charge is not conducive to rapid working, and that the output per given area of floor space is considerably less in an electric furnace. This is far from being the case. In a fuel-fired furnace the heating is localised and radiation from all the available wall area is never possible, which means that higher temperature gradients must prevail to transmit the heat to the more remote portions of the charge. In an electric furnace the heat can be radiated from all the available internal area, and in continuous furnaces the resistors are generally graded so that the inlet zones, which dissipate their heat to a cold charge, are more highly rated as the charge can absorb heat at a higher rate initially.

It is also not always realised that a mass of material

absorbs heat at a rate which is directly proportional to the difference (other things being equal) between the "skin" temperature and the temperature at centre. There is, therefore, a limit to the speed of working if overheating of the outer layers is to be obviated, and it is important to note that an electric furnace suitably designed will operate just below this limit of safety. Faster working, as sometimes witnessed in fuel-fired practice, is detrimental to the product, and, besides, is less amenable to control.

For low-temperature operations, 200° C.–650° C., combustion heating suffers from the inherent defect of high flame temperature, which makes control extremely difficult. With electric heating the low radiation transfer at these operating temperatures is compensated for by the provision of forced draught. A suitable motor-driven fan is used which circulates the air over the heating elements and through the charge. This enormously increases the speed of heat transfer while it minimises temperature differences in the charge, uniformity to between 2° and 4° C. being possible.

Turning to the question of furnace atmosphere, the great advantage of electric heating is that the atmosphere is independent of combustion, and almost any atmosphere can be used without the necessity for costly refractory muffles. Certain operations, such as the annealing of silicon steel transformer sheets, are being carried out in a controlled atmosphere carrying a high percentage of hydrogen without even a container or annealing box. Even if a container is desirable, it can be constructed of very light heat-resisting steel sheet, as it is not subjected to high flame temperatures or sulphur-bearing gases.

This question of the effect of atmosphere on metals is rapidly gaining the prominence it deserves, and manufacturers are awakening to the benefits of heat-treatment under controlled conditions which obviate surface defects, eliminate pickling, save metal losses, and minimise handling charges.

In a fuel-fired furnace, to reduce oxidation a smoky flame or an excess of gas must be carried, which lowers efficiency and in many cases introduces other defects. If copper is annealed in a reducing atmosphere a phenomenon known as "gassing" appears, which causes embrittlement, while brass is very susceptible to gases containing sulphur. Dezincification will also occur in brass if a reducing flame impinges on the surface. Oxidation is prevented at that point, and there is no film to prevent loss of zinc which will leave behind a familiar red stain. For high-carbon steel strip or wire, ordinary furnace atmospheres, whether so-called reducing or oxidising, will produce more or less decarburisation, which is only positively prevented by having an enclosed atmosphere with a predetermined CO/H_2 or CO/CO_2 ratio, which is possible with electric heating.

It must not be concluded that electric heating is ideally suitable and most economical for all heat-treatment operations. In our present state of development no heating medium holds a monopoly, and each has its field of usefulness. For instance, those processes which entail the heating of large masses of material of low intrinsic value, such as common steel forgings, iron castings, ingots, etc., where temperature control within 50° C. is not critical, no case can be made out for the flexible fuels, such as gas or electricity. This applies especially to processes which necessitate heating and cooling of the charge in the furnace, as the refractory materials which have to be heated possess a high thermal content, thus consuming a large amount of energy.

In a general review of this kind dealing with the applicability of electricity as a source of heat, it is not possible to particularise and describe specific uses of electric melting and heating. It is hoped that sufficient has been said to indicate the increasingly important rôle which electricity, as a source of heat, is playing in metallurgical processes, and to demonstrate the possibility, by its application, of the economic duplication of laboratory conditions in industry.

The British Industries Fair

THE British Industries Fair, to be opened in London and Birmingham on February 20, will surpass any of its predecessors in size and variety of products. While the enterprise of British manufacturers has necessitated a large extension of space, reports indicate that interest in the Exhibition is increasing abroad. Visitors are expected from about sixty different countries and states, many of whom will be supplied with information about the exhibits through advance catalogues which will enable them to save valuable time.

The phenomenal popularity of the Fair has made such demands on the space available that exhibitors have co-operated in a space-economy movement in order to meet the needs of all who desire to participate in the Exhibition. At the Birmingham section, for instance, many exhibitors have agreed to "double up" and share their allotted area with others, an action which caused the management to record their appreciation publicly. The results of the Ottawa Conference, and the fact that an increased number of leading manufacturers engaged in the heavy industries feel justified in making a new bid for world trade have increased interest in the Fair. This increased interest is undoubtedly due to the belief of many practical business men that trade is becoming more favourable to this country, and that the Fair is a practical method of taking advantage of the improved tendency.

The Exhibition will embrace a record display of an endless variety of products which will demonstrate the ability of the industries of Great Britain to compare favourably with any other country in regard to quality, workmanship, and price of product. Many noteworthy achievements will be exhibited, especially in the metallurgical section at Birmingham, where the indications point to a display superior to that of the 1932 Fair. Here the further applications of ferrous and non-ferrous metals will be demonstrated, especially developments in connection with corrosion and acid-resisting steels, and nickel and aluminium alloys. The modern trend of engineering calls for materials resistant to fatigue under great stress, and products will be available that are particularly suited to these conditions.

A wide range of light alloys will be on view, many of which have been developed to withstand exceptionally heavy stresses. These possess the combined merits of lightness, strength, and toughness, and products for use in aeroplane and motor-car production will indicate the progress achieved in reducing the weight-power ratio for transport purposes. Special prominence will be given to the corrosion-resisting qualities produced by the anodic oxidation of aluminium—an electro-chemical treatment which intensifies the natural oxide film which is always present on the surface of aluminium.

The practical application of both ferrous and non-ferrous metals in buildings will be demonstrated. In many cases stands will be built almost entirely in stainless steel or in non-ferrous metals, and these will display sheets, sections, and tubes in endless variety of finish and shape. Examples of seamless tube will be displayed, which will include copper and brass tubes of 6 in., 12 in., and 18 in. diameter; copper housing pipes for water and heating services; cupro-nickel condenser tubes, and aluminium condenser tubes; locomotive boiler tubes in copper and brass; copper-coated steel condenser and superheater tubes; copper and brass rods for the motor and electrical trades; coils of tubing for panel heating; phosphor bronze sheet, wire, and ingots of various alloys.

The Fair will be representative of practically every phase of British industry, the diversity of which has few parallels in other countries. It is, in fact, everybody's Fair, and the Board of Management has every reason to believe that the number of potential buyers visiting it will far exceed any previous Fair held in this country, and it behoves everyone in this country to render all possible assistance towards the complete success of the effort.

Some Recent Inventions.

The date given at the end of an abridgement is the date of the acceptance of the complete Specification. Copies of Specifications may be obtained at the Patent Office, Sale Branch, 25, Southampton Buildings, London, W.C. 2, at 1/- each.

Machines for the Centrifugal Casting of Metals.

SOME recent improvements in the design of machines for the centrifugal casting of metals have been developed primarily with the object of facilitating the ejection of the finished casting from the mould. In this instance, reference is made to machines which are designed to cast cylindrical blanks for gear-wheels by the centrifugal process. A sectional elevation of a machine which embodies an improved device is shown in Fig. 1. In this case the bottom mould plate A is arranged to have vertical movement in relation to the mould ring B, so that when separation has been effected between the latter and a top mould plate C, the vertical movement will raise the casting out of its mould ring.

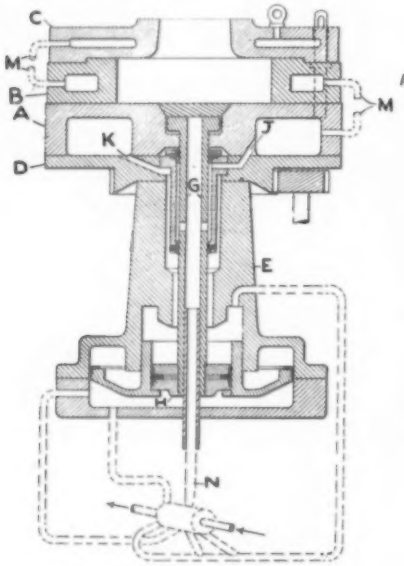


Fig. 1.—Machine for casting metal centrifugally.

The bottom mould plate is secured to a baseplate D, which is mounted so that it will rotate on a support E. The centre part F of the bottom mould plate is lifted vertically by means of a hollow spindle G extending through an axial bore in the support E, and having secured upon its lower end a piston H working in a cylinder located in the lower part of the support. Connections from the upper and lower ends of the cylinder to a rotary valve enable liquid pressure to operate the piston, so that the part F of the bottom mould plate may be raised or lowered.

Attention is also directed to more effective provision for cooling the mould. This is effected by providing in the mould ring or bottom mould plate a water-cooling chamber through which water can be circulated by way of connections from vertical inlet and outlet passages. Connections at M may lead water to the chambers in the bottom plate, mould ring, and top plate, while a connection N leads from the lower end of the spindle to the rotary valve or such means employed to supply the coolant.

In the sequence of operations, the top plate is lowered on the mould ring and secured. Metal is poured into the mould and the mould is rotated. When the rotation of the mould is stopped water is forced up through the spindle G, and by way of ports and a passage J enters the various cooling chambers, the water then flowing back through passage K to be ultimately exhausted. The top plate is then removed, and the valve operated to cause part of the lower mould plate to be raised, thus ejecting the casting from its mould. Reference is made to a modified arrangement.

372,439. DAVID BROWN AND SONS (HUDDERSFIELD), LTD. May 12, 1932.

Electric Resistance Furnace Improvements.

IN electric furnaces of the resistance type heat is normally distributed through the resistance material in a zone or zones each of which is most intense along the straight line joining the electrodes, and the isobars generally take a similar shape to the lines of force between the magnetic poles. In a suggested improvement, in which a crucible is embedded in a resistance material, the furnace is designed for three-phase current, and the heat is concentrated and the current conducted around the crucible for the charge. This is effected by a hollow block forming a neutral electrode of greater electrical conductivity than the resistance material which separates it from the live electrodes.

The method employed is indicated in Fig. 1. The resistance material A is contained in a triangular chamber of suitable refractory material. The hollow block B, which is preferably of graphite or amorphous carbon, forming a neutral electrode of greater conductivity than the resistance material, is located about the crucible, and the chamber is shaped so that the live electrodes C will occupy the corners. It is claimed that this method enables the heat to be distributed more regularly about th crucible

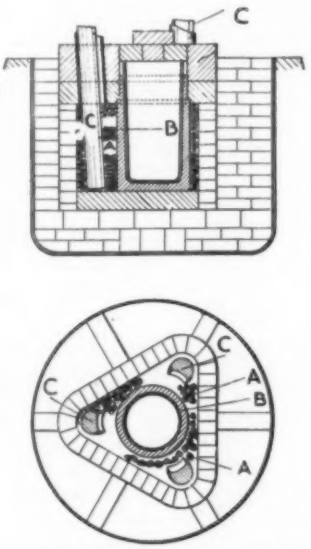


Fig. 1.—Electric resistance furnace.

376,093. REGINALD A. BEDFORD, of Sheffield. July 7, 1932.

A Burner for Surface-hardening Steel Parts.

THE surface of steel parts required to be hardened must be heated within very narrow limits in order to avoid overheating the part; at the same time, it is necessary to supply ample heat, so that the temperature of the surface treated will be above the hardening temperature. Investigations have shown that slight differences in the development of the flame, and consequently the speed of heating, cause considerable differences in the hardness of the hardened layer which influence the resistance to wear of the parts treated.

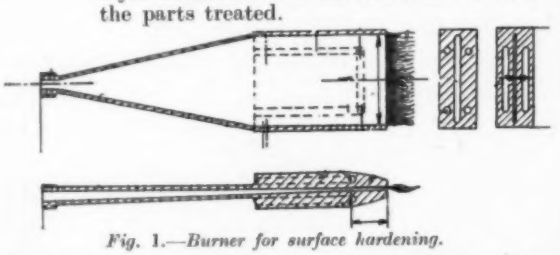


Fig. 1.—Burner for surface hardening.

In order to obtain a satisfactory and completely uniform hardening of large surfaces a hardening flame is required, the effective core portion of which burns perfectly evenly throughout the whole section, and which shows no irregularities whatever. For this purpose a number of slot-burners have been designed in which the channel connecting the burner slot with the mixing chamber is greater in length than the said slot. This arrangement is claimed to permit a turbulent flow of the gases being burned, and a flame is obtained possessing an active core which extends uniformly beyond the burner slot. One constructional form is illustrated in Fig. 1, showing modified arrangements for water cooling around the tip of the burner.

377,488. DEUTSCHE EDELSTAHLWERKE AKTIENGESELLSCHAFT, of Germany. July 28, 1932.

Phosphorus in Cast Iron

By Walter West
(*Leyland Motors Ltd.*)

High test qualities and solidity are the primary requirements of iron castings for high-duty applications; they are intimately associated with the constitution and structure of the irons used, and in a paper, given before the Lancashire Branch of the Institute of British Foundrymen, the author gives results of investigations that indicate the importance of low phosphorus in the irons used in meeting these requirements.

DURING the last two decades there has been a great revision of opinion among the founders of cast iron. At one time it was thought that pig iron had hereditary properties, mostly bad, which were the cause of many wasters in the foundry. This opinion may not now be so prevalent, though there is still some little truth in the supposition. The physical characters of pig irons are greatly influenced by variations in blast-furnace operations, and two pig irons with identical compositions may still be radically different from each other in physical properties, even after a remelting process in the cupola. Foundrymen, however, are not looking for a millennium period of perfect pig iron for perfect castings, but rather to obtain pig iron of more or less constant composition and physical properties, and on this point the so-called refined irons fill the breach.

In a great measure, improvement in the properties of cast iron has come through a better understanding of the influence of various elements and compounds which contribute to its constitution. The use of steel additions to the mixtures for casting purposes was but a prelude to the great demand that exists to-day for special refined iron, "so called" because of the increased mechanical results and sounder castings obtained from the use of them.

These two outstanding requirements of the foundryman for high mechanical tests and solidity in the cast iron are intimately linked with its constitution and structure. Constitution is derived from the chemical nature of the different elements and compounds, and the relative proportions of them present. Structure is the size and arrangement of the constituents, and is largely governed by the rate of cooling, and secondly by the proportions of the respective constituents. If cast iron be considered for a moment in the light of a carbon-iron alloy, and assuming the other constituents usually present to exert no influence, it becomes evident that the proportion of carbon which can be taken into solution in iron at different temperatures is a factor of great importance.

It is definitely known with a degree of accuracy that iron takes up at its melting point 4·3% carbon, and, because of its characteristic solidification point of 1,135° C. is known as the carbon eutectic. The presence of more, or less, than this percentage of carbon has its corresponding effect upon the structure and the solidification point of the iron. The addition of other elements, such as silicon, manganese, phosphorus, and sulphur, modifies the carbon percentage at which the eutectic is formed, and thereby the solidification point of the alloy. For example, in an ordinary iron alloy the presence of 2% silicon and 1% phosphorus produces a eutectic composition when the carbon content is approximately 3·4%.

In addition to the effect of these other elements contained in the pig iron, and their effect upon the ultimate structure, consideration must be given to the rate at which the liquid iron cools to the solid state. Among all the constituents of the composition of cast iron, carbon, which exists in the free or graphitic condition, predominates, but the degree to which it does so depends largely upon the amounts of the other constituents and the rate of cooling of the alloy.

Thus the development of the combined carbon matrix has been largely fostered of late years, and, in the production of higher mechanical strength properties, a maximum of pearlite, or combined carbon eutectoid, in the structure has proved highly successful, more especially where the total amount of carbon has been kept lower than usual. In the production of grey cast iron for strength and solidity, thought and control have been concentrated chiefly on the respective amounts of total carbon and silicon the material contained.

It is common knowledge that the element, silicon, exercises an influence similar to that of the cooling rate because, as the proportion of this element increases so do the properties of iron improve towards the point of maximum pearlitic structure or combined carbon eutectoid; further additions of silicon beyond this point cause a diminution in strength and an increase in openness or porosity, where all other factors are constant. Obtaining a maximum pearlitic structure or combined carbon eutectoid, however, without a neutralising effect of large precipitated graphite flakes, demands a restriction of the amount of total carbon.

The work of Hamasumi, Honda, Merakami, confirms that there does exist a range of silicon contents, between 1·0 and 2·5%, in which an increase of this element is followed by an increase in graphite, and such a diminution of carbon in this eutectoid that the constitution remains graphite-pearlitic. The lower the total carbon, the greater is this range, and where this is reduced to approximately 2·4%, and a high figure of silicon is chosen—say, 3·0 to 3·5%,—it is possible to obtain such proportions that cooling speeds within certain limits have no effect upon the structure, and the mechanical properties are the same, irrespective of wall thickness.

To speak of these possibilities in theory, despite their convincing character, is of quite a different order from carrying them out in practice. The multiplicity of other factors, which enter in the problem of effecting improvements in strength and solidity of cast-iron castings, cannot very well be ignored. Items such as the size and disposition of runners through which the metal is poured, the nature of the material into which it is cast, the effect of superheat, etc., only point to the complexity of the problem, but, at this juncture, it is intended to keep them in mind only.

This theoretical view, however, is of primary importance to the foundry industry, where increased strength properties are required. High strengths hitherto unknown have been, and are now being, produced from cupola melting by the use of so-called "refined irons," having lower total carbon contents than those produced direct from the blast furnace. The availability of these "refined irons" has made it possible for the general run of foundrymen, who have no special technical knowledge at their disposal to control the relative proportions of the constituents in the cast iron used, to produce a shorter freezing range alloy, and thus overcome much of the porosity which is the commonest of foundry accompaniments.

It is not to be accepted, however, without question that the whole secret of the value of remelted irons is bound up with the lower total carbon contents they contain, nor yet with the refined grain of the graphitic carbon, which unquestionably is of value, more particularly where higher strength is desired of the cast-iron mixture.

This discussion is an attempt to show that with most

"refined irons," so-called, there is invariably one other attendant factor which largely contributes to the successful

Tc, 3·27; Si, 2·08; Mn, 0·90; S, 0·05; Cr, 0·25; 0·12% P.

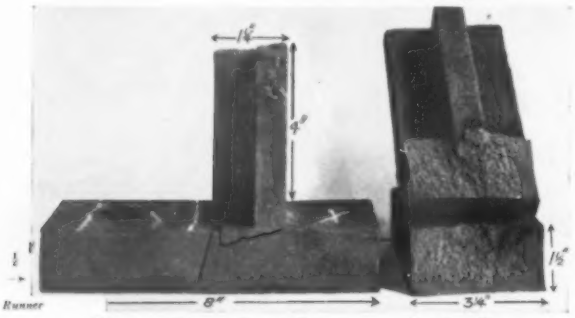


Fig. 1.—Shape of test-piece. *Fig. 2.—Fracture.*

results which have and are being obtained in the production of solidity in thick and uneven sections of castings. Most of these particular remelted irons have their origin in the form of higher carbon pig iron, which element is reduced in the remelting process by the addition of an appreciable proportion of steel scrap, or the removal of some of it by oxidation, either by tropenising it or by oxidation in Siemen's open-hearth practice.

With the introduction on a commercial scale of the pulverised fuel furnace, unlimited scope is put into the hand of the remelted-iron producer for the use of any kind of material whose chief constituent is iron. The outstanding feature, however, of most successful remelted irons is not the low total carbon content, but rather the low phosphorus percentage they contain.

As far back as the so-called semi-steel, the great feature of the remelting mixture of steel and pig iron was the low phosphorus content—not because it was specifically sought after and produced, but rather that it became a natural sequence of such additions of steel having low phosphorus contents. Taking a review of all the special irons which have appeared—and in some cases disappeared—low phosphorus was an attendant factor. The fact still remains true with those remelted irons which have definite claims to no association with scrap of any sort; the basis of such product invariably is found to be a hæmatite iron.

The determination of the total shrinkage of cast iron due to liquid and solidification shrinkage has been the object of many researches. Smalley[1] carried out a series of experiments on grey cast iron by casting conically-shaped specimens to determine any relation between the volume changes taking place during solidification and the tendency to form a pipe. Longden[2] also employed cylinders and spheres fed and unfed in order to measure the degree of liquid shrinkage in grey cast iron. Schwartz and others

Tc, 3·27; Si, 2·00; Mn, 0·93; S, 0·05; Cr, 0·32.
0·29 P. 0·50 P. 0·63 P.

Fig. 3.—Representative Fractures.

have used various methods to the same end, and these have been carried out more on practical lines than as academic experiments.

1 "Proceedings Inst. Brit. Foundrymen," vol 16 (1922-23), p. 405.
2 "Proceedings Inst. Brit. Foundrymen," vol. 18 (1924-25), p. 573.

While many criticisms may be made of such methods of determination because the figures obtained may not actually represent true value, and also there is no differentiation between the shrinkage arising from liquid contraction and that due to contraction through solidification, the comparative results have great usefulness in foundry practice.

The results obtained by these research workers do not directly indicate any relation between the phosphorus content and total shrinkage in grey cast iron. Smalley indirectly mentions the effects of phosphorus, but this occurs more as an impression of personal opinion than a series of directed experiments to determine its influence.

Phosphorus and Casting Porosity.

To directly determine any relationship that may exist, tests were designed which would be as closely allied to foundry practice as is possible. All moulds were made of dry sand, with one exception, and no sand cores were used, so that gas generation in the mould might be reduced in quantity to the lowest limit. Runners attached to the moulds were all of a standard size and pattern, and in all the foundry technique was meticulously watched to avoid any variable factor.

The cast iron used for the experiments was built up from one common base—*i.e.*, a low-phosphorus haematite—to which, for sake of convenience, ferro-phosphide was added in predetermined amounts to give the phosphorus contents

Tc, 3·3; Si, 2·00; Mn, 0·90; S, 0·05; Cr, 0·33.
0·72 P. 0·91 P. 1·09 P.

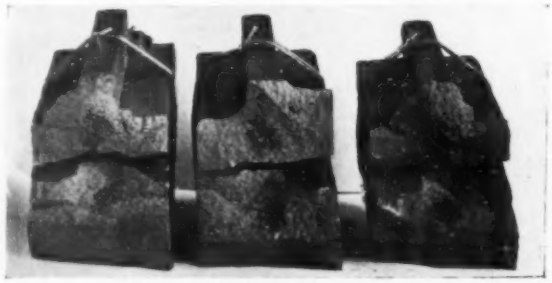


Fig. 4.—Representative Fractures.

required. Temperatures of all mixtures were kept as near as possible around 1,300° C., and tapped from a cupola into a hand shank, and then into the moulds.

Experimental Tests.

Porosity Test 1.—For this experiment a cruciform section of test-piece was used, having the shape and size as represented by Fig. 1. The mould was of green sand, fairly dry, and poured with the cruciform section in the top part. The castings were allowed to cool in the mould, and when cold the section at the base of the pillar was sectioned horizontally and vertically. Photographs of representative fractures are reproduced in Figs. 2, 3, and 4.

Solidity as represented by Fracture.

Analysis.						Results.
T.C.	Si.	Mn.	S.	P.	Cr.	
3·27	2·08	0·91	0·045	0·12	0·27	Sound in fracture.
3·36	2·10	0·92	0·060	0·15	0·33	Ditto.
3·30	2·00	0·90	0·040	0·24	0·30	Ditto.
3·27	2·10	0·93	0·036	0·29	0·32	Traces of sponginess.
3·35	2·04	0·89	0·050	0·36	0·31	Ditto.
3·30	2·10	0·82	0·055	0·50	0·40	Definite spongy patch.
3·35	2·04	0·86	0·048	0·63	0·36	Large and definite spongy patch.
3·36	2·10	0·90	0·060	0·72	0·32	Ditto.
3·30	2·12	0·80	0·055	0·78	0·36	Increased spread of spongy patch.
3·24	2·12	0·75	0·060	0·91	0·42	Ditto.
3·24	2·12	0·76	0·052	1·09	0·42	Ditto.

Porosity Test 2.—At the suggestion of Mr. P. A. Russell, chairman of the Cast Iron Sub-Committee of the Technical Committee of the Institute of British Foundrymen, two sets of solid blocks were cast, one series without feeding heads, and the other with feeding heads. The blocks were 3½ in. wide, 4 in. long, 3 in. deep, and cast in dry sand moulds (Fig. 5). In the top face of the block two holes were drilled, 1½ in. diameter × 2½ in. deep, $\frac{5}{16}$ in. apart. Each hole was threaded at its mouth for a sufficient distance to enable a water connection to be attached.

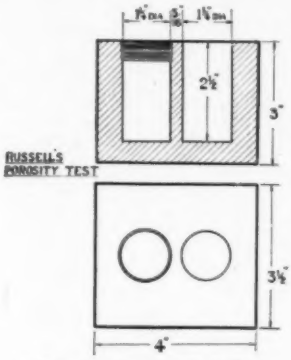


Fig. 5.—Porosity test-piece.

Each hole had water pressure applied to 500 lb. per sq. in. separately; any leakage through the $\frac{5}{16}$ in. partition was noted in the other hole. This test was extremely searching, inasmuch as the partition of metal between the holes represented the centre of the block.

Results from Water Tests.

BLOCKS WITHOUT FEEDER HEADS.

Analysis.						Results.
T.C.	Si.	Mn.	S.	P.	Cr.	
3·30	1·80	0·80	0·050	0·080	0·30	O.K. at 500 lb. pressure.
3·27	1·92	0·80	0·050	0·180	0·27	,, 510 lb. ,,
3·30	1·94	0·84	0·052	0·320	0·31	,, 500 lb. ,,
3·27	1·90	0·80	0·054	0·450	0·33	,, 500 lb. ,,
3·30	1·95	0·85	0·050	0·440	0·29	,, 500 lb. ,,
3·33	2·00	0·86	0·052	0·530	0·26	Leaking without pressure
3·28	2·00	0·84	0·059	0·660	0·30	Ditto.
3·30	2·00	0·90	0·056	0·84	0·28	Ditto.
3·30	2·00	0·90	0·050	0·85	0·27	Ditto.
3·27	2·10	0·92	0·055	0·97	0·29	Ditto.
3·27	2·00	0·90	0·052	1·18	0·35	O.K. at 500 lb. pressure
3·30	2·10	0·94	0·056	1·17	0·40	Leaking without pressure
3·30	2·00	0·92	0·050	1·52	0·36	Ditto.

BLOCKS WITH FEEDING HEADS.

3·40	2·16	0·89	0·042	0·56	0·25	O.K. at 500 lb. pressure
3·41	2·10	0·90	0·045	0·66	0·25	Leaking without pressure
3·39	2·12	0·92	0·046	0·79	0·23	O.K. at 500 lb. pressure.
3·27	2·10	0·90	0·042	0·76	0·30	,, 500 lb. ,,
3·25	2·10	0·90	0·045	0·92	0·30	,, 500 lb. ,,
3·27	2·10	0·89	0·050	1·01	0·30	,, 500 lb. ,,
3·27	2·10	0·90	0·037	1·19	0·38	Leaking without pressure

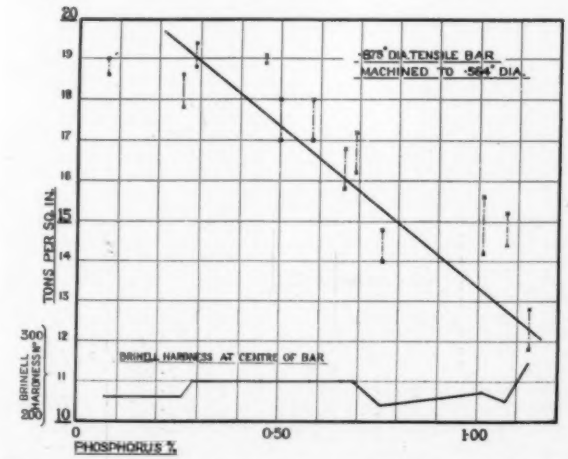


Fig. 6.—Tensile tests on 0·875 in. dia. bar, machined to 0·564 in dia.

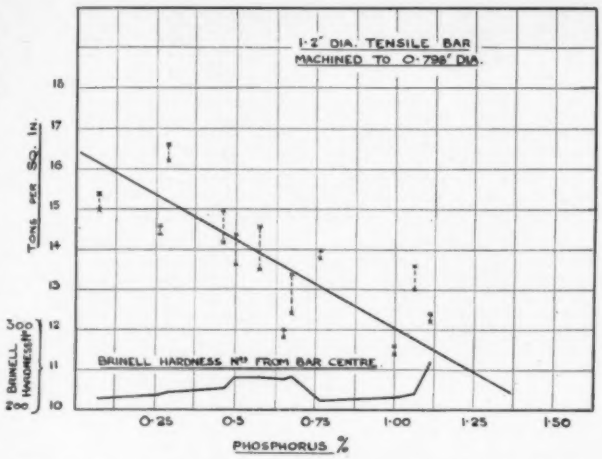


Fig. 7.—Tensile tests on 1·2 in. dia. bar, machined to 0·798 in. dia.

Porosity Test 3.—An entire departure from experimental shapes was attempted in this set of experiments. Automobile-head castings of a design notorious for the development of porosity were made in irons having the same composition except for an increasing phosphorus content. The resulting castings were machined top and bottom, and the bosses drilled in the usual way. Water pressure was applied to the inside jacket of the casting, and any leakage through the bosses was easily discerned. All castings reported as leaking were sawn up into sections across the leaking parts, and examined, with a report of the conditions as follows :—

Development of Porosity in Automobile Castings.

Analysis.						Results.
T.C.	Si.	Mn.	S.	P.	Cr.	
3·30	1·90	0·80	0·060	0·045	0·31	O.K. on water test.
3·36	1·90	0·81	0·062	0·110	0·27	Ditto.
3·37	1·90	0·80	0·058	0·110	0·33	Ditto.
3·30	1·90	0·80	0·050	0·26	0·30	Leaking, spongy in bosses.
3·36	1·90	0·79	0·048	0·30	0·32	Ditto.
3·33	1·94	0·81	0·058	0·41	0·27	Ditto.
3·30	1·92	0·82	0·058	0·49	0·30	Ditto.
3·27	2·00	0·80	0·060	0·65	0·34	Ditto.
3·33	2·00	0·78	0·060	0·79	0·25	Ditto.
3·39	2·00	0·75	0·058	0·86	0·25	Ditto.

Consideration of Porosity Results.

The outstanding feature of all the experiments detailed in this paper is the effect of phosphorus on the soundness of a cast-iron section. The three sets of porosity experiments cover the junction of sections in a medium size of casting, a heavy solid block, and commercial type of casting, which necessitate the use of internal cores, and must stand to water pressure. Under 0·3% phosphorus provides a sound range of compositions in each set of experiments, and these may be taken without much question as representing three differing types of sections and designs.

The range of total carbon and silicon contents rather lend confirmation to the results, for had either of these factors been present in a lesser amount than stated, this fact could only have caused the sections to have had a closer grain and drawn to a lesser degree. Further experimenting could be carried out in a similar manner with series of lower total carbon and silicon contents, and the results would provide us with a wider range of information. It is, however, always desirable from a machining point of view to maintain cast-iron castings with the maximum degree of softness in these days of production, providing

always that such softness is commensurate with the measure of strength and solidity in the section as required.

A further factor, which has now been proved as a result of these experiments, is that to consider a carbon-silicon balance only to effect soundness in cast-iron sections, is totally inadequate to enable a correct control and results to be obtained. Where sections in a casting materially differ in dimensions it is the most difficult task, that a foundryman can be set, to control these two elements without having hardness in the thin sections on the one hand, or porosity in the thick sections on the other.

Total carbon-silicon control is maintained with great accuracy in the normal operations of melting cast iron in a cupola for such castings with a diversity of sections. Analysis of the mixture aimed at was: Total carbon, 3·2%; silicon, 1·40%. A greater limit than 0·1% silicon or 0·2% total carbon variation would cause one of two extremes—*i.e.*, hardness or porosity—to be experienced during machining. The phosphorus content by design was maintained at 0·6% to 0·7%. The effect of reducing the phosphorus content of the mixture to under 0·3% has had the remarkable effect of allowing with the same total carbon content a wide variation of silicon to the extent of 0·5%, without the occurrence of either hardness or porosity should the extremes be touched.

This phase of phosphorus interference is of utmost importance to all foundrymen, especially for those who are depending upon an outside source for their supply of scrap cast iron, and also for those who must produce castings to withstand pressure of any kind.

Phosphorus and Keep's Contraction Test.

The usual procedure was followed as laid out for this test—namely, the casting of two bars, 24 in. × 1 in. × 1 in., run from one end and cast flat in an iron frame, which has its inside faces accurately machined. The contraction is then measured by means of a wedge pushed between the bars and the end of the frame, a pop mark being made on the wedge at the point of contact. The wedge is then withdrawn from the frame and its thickness on the pop mark measured by a micrometer.

Influence of Phosphorus on Contraction (Fig. 9).

Analysis.						Contraction.
T.C.	Si.	Mn.	S.	P.	Cr.	
3·37	1·92	0·81	0·056	0·085	0·27	0·331
3·37	1·94	0·80	0·056	0·350	0·27	0·309
3·27	2·00	0·80	0·056	0·720	0·25	0·315
3·40	2·02	0·82	0·060	0·930	0·27	0·307
3·40	2·00	0·76	0·060	1·20	0·27	0·297
3·33	2·00	0·78	0·060	1·43	0·24	0·291

Phosphorus and Chill Test from Keep's Test.

1½ in. was sawn from the chilled end of each bar and ½ in. hole drilled as far as possible in the direction of the chill from the soft end. The pieces were then split by means of a steel wedge and the chill measured.

Influence of Phosphorus on Depth of Chill.

Analysis.						Contraction. In.
T.C.	Si.	Mn.	S.	P.	Cr.	
3·37	1·92	0·81	0·056	0·085	0·27	½
3·37	1·94	0·80	0·056	0·350	0·27	½
3·27	2·00	0·80	0·056	0·720	0·25	¾
3·40	2·02	0·82	0·060	0·930	0·27	⅞
3·40	2·00	0·76	0·060	1·200	0·27	⅞
3·33	2·00	0·78	0·060	1·430	0·24	1

Effect of Phosphorus on Tensile Strength.

Round test-bars of varying diameters to the B.S.I. specification requirements were cast on end in oil-sand cores, the metal being run in at the top of the mould, and provided with head metal to ensure soundness.

MECHANICAL TEST RESULTS.

Size of Test Bar, 0·875 in. (Fig. 6).

As Cast Diameter: 0·875 in. Machined Diameter: 0·564 in

Analysis.						Max. Stress in Tons per Sq. In.	Brinell Hardness No. Cr. of as Cast Bar.
T.C.	Si.	Mn.	S.	P.	Cr.		
3·27	2·00	0·89	0·040	0·070	0·28	18·6	229
						19·2	229
3·33	2·08	0·87	0·050	0·26	0·36	18·6	229
						17·8	229
3·27	2·10	0·93	0·036	0·29	0·32	18·8	255
						19·4	241
3·33	2·10	0·85	0·048	0·46	0·38	19·2	241
						19·0	255
3·30	2·10	0·86	0·055	0·49	0·40	17·0	241
						18·0	255
3·30	2·10	0·81	0·055	0·58	0·30	17·0	241
						18·0	255
3·27	2·14	0·92	0·044	0·66	0·28	16·8	241
						15·8	241
3·30	2·10	0·77	0·060	0·69	0·31	16·2	255
						17·2	245
3·27	2·12	0·91	0·044	0·76	0·27	14·0	229
						14·8	229
3·27	2·14	0·78	0·052	1·01	0·30	15·6	229
						14·2	241
3·30	2·08	0·89	0·052	1·07	0·35	14·4	255
						15·2	255
3·27	2·20	0·92	0·048	1·13	0·27	12·8	269
						11·8	269

Size of Test Bar, 1·20 in. (Fig. 7.)

As Cast Diameter: 1·20 in. Machined Diameter: 0·798 in.

3·27	2·00	0·87	0·04	0·070	0·28	15·0	202
						15·4	229
3·33	2·08	0·87	0·05	0·26	0·36	14·6	219
						14·4	219
3·27	2·10	0·93	0·036	0·29	0·32	16·2	217
						16·6	229
3·33	2·10	0·85	0·048	0·46	0·38	15·0	229
						14·2	229
3·30	2·10	0·86	0·055	0·49	0·40	13·6	241
						14·4	241
3·30	2·10	0·81	0·055	0·58	0·30	14·6	241
						13·5	241
3·27	2·14	0·92	0·044	0·66	0·28	11·8	241
						12·0	229
3·30	2·10	0·77	0·060	0·69	0·31	12·4	241
						13·4	241
3·27	2·12	0·91	0·044	0·76	0·27	13·8	207
						14·0	217
3·27	2·14	0·78	0·052	1·01	0·30	11·4	217
						11·6	217
3·30	2·08	0·89	0·052	1·07	0·35	13·6	229
						13·0	217
3·27	2·20	0·92	0·048	1·13	0·27	12·2	269
						12·4	255

Size of Test Bar, 2·2 in. (Fig. 8.)

As Cast Diameter: 2·20 in. Machined Diameter: 1·785 in.

3·37	1·92	0·81	0·056	0·085	0·27	11·47	170
						8·03	—
3·37	1·94	0·80	0·056	0·35	0·27	9·03	170
						10·55	—
3·36	2·00	0·82	0·058	0·47	0·25	8·03	170
						9·71	—
3·36	2·00	0·78	0·056	0·56	0·25	8·75	179
						10·11	—
3·27	2·00	0·80	0·056	0·72	0·25	9·74	149
						9·59	—
3·40	2·02	0·82	0·060	0·93	0·27	5·19	149
						5·13	
3·40	2·00	0·76	0·060	1·20	0·27	5·55	179
						6·07	—

Consideration of Keep's Test Results.

So many factors are involved in the carrying out of this test, and which can affect the results, that many workers do not consider the results obtained therefrom of much importance. The results, however, in this case are comparative and are given for interest's sake only. An increase of phosphorus content in these experiments has caused a reduction in the total contraction which is not inconsiderable, and is worthy of note.

The results obtained from the chill-test sections cut from the Keep's test-bars are but a confirmation of the value of low phosphorus irons to the chill-roll makers.

Consideration of Tensile Test Results.

The results shown in each series are from duplicate bars, and in some cases the variations between them and in comparison with their neighbours are not easily explained. The results plotted as graphs, however, give a general idea, and it is interesting and rather remarkable

Fig. 9.—Contraction Results.

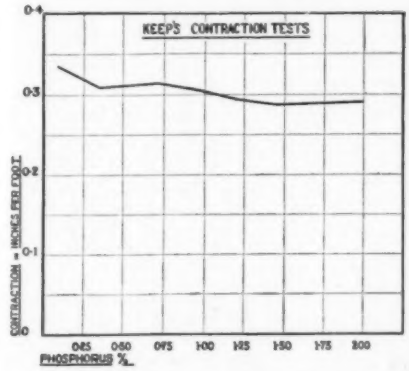
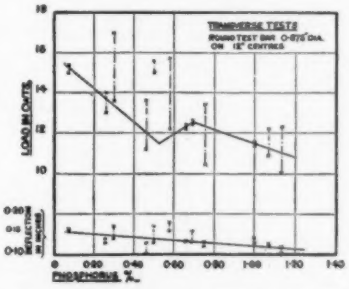


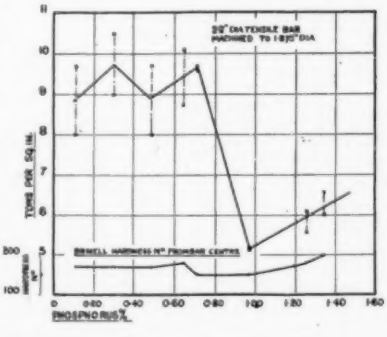
Fig. 10.—Transverse tests on 0·875 in. dia. bars on 12 in. centres



that with each size of bar there is an increase in the tensile strength as the phosphorus rises to 0·3%. This coincides with the work of Wüst and Mackenzie, who found that the maximum strength of a series of cast-iron test-pieces was reached with a phosphorus content of 0·3%, after which there occurred a gradual decrease in this value.

With the 2·2 in. bars, however, the higher strength would appear to be maintained up to a phosphorus content of 0·70%. This occurrence may be due to the selective segregation of the phosphide to the centre of the test-pieces, as in contrast to a more even distribution in the smaller size of bars.

Fig. 8.—Tensile tests on 2·2 in. dia. bar, machined to 1·875 in. dia.



Consideration of Hardness Results.

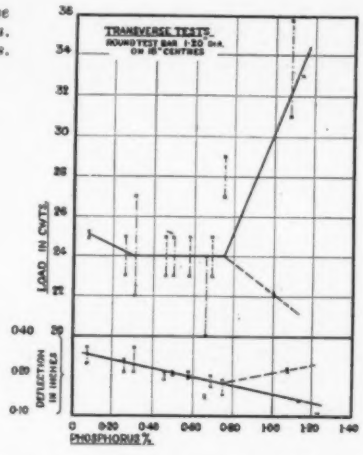
Brinell hardness tests were taken with a 10 mm. ball and 3,000 kg. pressure on the centre of the section with each test-piece of the series. The results are plotted below the tensile strengths of each respective series. In the smaller sizes of bars there occurs a definite rise in hardness number as the phosphorus increases, but this is not shown so in the 2·2 in. bar series; in fact, there occurs a slight drop as the phosphorus content increases. This phenomenon may arise from the presence of a certain degree of openness of fracture, or porosity, which would occur at the centre of the bar in this, the thickest section of bars.

Phosphorus: Comparative Analysis in Spongy Areas and Solid Areas.

Samples for analysis were taken from the spongy areas of the cruciform test-bars by means of a very small drill, and also from solid portions of the same bar, and these are tabulated with the initial phosphorus content of the ladle from which each bar was cast.

	%		%
Ladle 5A	0·69	*Ladle* 6	0·91
Test Bar, solid part	0·67	Test Bar, solid part	0·93
,, spongy part...	0·50	,, spongy part ...	0·68
	%		%
Ladle 5	0·78	*Ladle* 7	1·09
Test Bar, solid part	0·80	Test Bar, solid part	1·12
,, spongy part...	0·63	,, spongy part ...	0·97

Fig. 11. — Transverse tests on 1·20 in. dia. bars on 18 in. centres.



Effect of Phosphorus on Traverse Strength.

Standard test-pieces of three sizes were cast on end in a similar way to the tensile pieces. The results have been corrected for any inaccuracy in dimension at the point of fracture, and are given as follows. The range of compositions of the irons is common to the set of three tests.

Transverse Test Results

Size of Test Bar, 0·875 in. (Fig. 10.)

Corrected Diameter: 0·875 in. Centres: 12 in.

Analysis.						Fracture Dia.	Load, Cwt.	Deflection, In.
T.C.	Si.	Mn.	S.	P.	Cr.			
3·27	2·00	0·87	0·04	0·070	0·28	0·860	15·08	0·162
						0·860	15·45	0·162
3·33	2·08	0·87	0·05	0·26	0·36	0·830	14·4	0·141
						0·830	12·85	0·126
3·27	2·10	0·93	0·036	0·29	0·32	0·860	13·65	0·142
						0·860	17·10	0·173
3·33	2·10	0·85	0·048	0·46	0·38	0·820	10·65	0·138
						0·820	13·65	0·106
3·30	2·10	0·86	0·055	0·49	0·40	0·830	15·6	0·137
						0·840	15·0	0·176
3·30	2·10	0·81	0·055	0·58	0·30	0·860	14·85	0·162
						0·860	12·23	0·183
3·27	2·14	0·92	0·044	0·66	0·28	0·850	12·44	0·133
						0·860	12·32	0·132
3·30	2·10	0·77	0·060	0·69	0·31	0·860	12·63	0·153
						0·860	Blown	0·132
3·27	2·12	0·91	0·044	0·76	0·27	0·860	13·50	0·132
						0·860	10·50	0·112
3·27	2·14	0·78	0·052	1·01	0·30	0·860	11·4	0·142
						0·860	11·6	0·132
3·30	2·08	0·89	0·052	1·07	0·35	0·870	10·9	0·122
						0·860	12·2	0·122
3·27	2·20	0·92	0·048	1·13	0·27	0·850	9·7	0·103
						0·870	12·3	0·122

TRANSVERSE TEST RESULTS—*continued.*

Size of Test Bar: 1·20 in. (Fig. 11.)

Fracture Dia., In.	Corrected Dia., In.	Load, Cwt.	Centres, In.	Deflection, In.
1·25	1·20	25·0	18	0·230
1·25	1·20	25·4	18	0·270
1·25	1·20	23·0	18	0·210
1·25	1·20	25·0	18	0·240
1·25	1·20	27·0	18	0·270
1·25	1·20	22·0	18	0·210
1·25	1·20	25·0	18	0·192
1·25	1·20	23·0	18	0·210
1·28	1·20	22·7	18	0·200
1·25	1·20	24·9	18	0·210
1·25	1·20	24·9	18	0·210
1·25	1·20	23·0	18	0·192
1·25	1·20	20·0	18	0·154
1·25	1·20	24·0	18	0·154
1·25	1·20	23·0	18	0·173
1·25	1·20	25·0	18	0·202
1·25	1·20	29·0	18	0·192
1·25	1·20	27·0	18	0·154
1·20	1·20	19·0	18	0·190
1·20	1·20	18·0	18	0·180
1·25	1·20	31·0	18	0·210
1·28	1·20	35·8	18	0·220
1·25	1·20	33·0	18	0·145
1·25	1·20	Blown	18	0·145

Size of Test Bar: 2·20 in. (Fig. 12.)

Fracture Dia., In.	Corrected Dia., In.	Load, Cwt.	Centres, In.	Deflection, In.
2·20	2·20	140·6	18	0·260
2·20	2·20	137·6	18	0·250
2·20	2·20	124·0	18	0·241
2·25	2·20	133·0	18	0·250
2·20	2·20	134·8	18	0·250
2·22	2·20	132·4	18	0·240
2·22	2·20	107·4	18	0·222
2·22	2·20	135·4	18	0·232
2·22	2·20	116·0	18	0·220
2·22	2·20	137·0	18	0·184
2·22	2·20	113·0	18	0·180
2·25	2·20	135·0	18	0·220
2·22	2·20	Blown	18	0·186
2·22	2·20	131·0	18	0·220
2·25	2·20	107·6	18	0·210
2·25	2·20	111·6	18	0·211
2·22	2·20	98·0	18	0·147
2·22	2·20	123·0	18	0·207
2·20	2·20	85·0	18	0·198
2·28	2·20	96·0	18	0·185
2·25	2·20	122·0	18	0·180
2·22	2·20	106·0	18	0·164
2·25	2·20	104·0	18	0·157
2·22	2·20	104·0	18	0·180

The results from these tests are not so distinct in their evidence as the tensile results, but in the smallest size of bar there occurs a definite drop in the transverse strength until the phosphorus content reaches 0·50% when an increase persists until 0·70% is attained, when a decrease continues until the end of the series.

Within the heaviest bar series—that is, the 2·2 in. diameter,—a consistent drop in strength proceeds throughout the series. The results obtained from the 1·20 in. diameter series are interesting from the point of view that the decrease in strength is much less marked with the lower increase of phosphorus contents, but at 0·30% this decline is arrested, and continues to 0·75%, when the results become directly contrary.

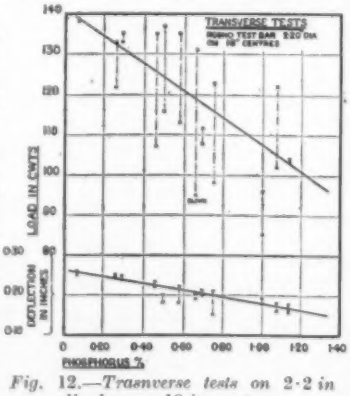


Fig. 12.—Transverse tests on 2·2 in dia. bars on 18 in. centres.

There is more evidence towards an upward trend of the tail than otherwise, but the confliction of the results needs further confirmation.

Consideration of Deflection Results.

The brittleness imparted to cast iron by the presence of increasing amounts of phosphorus is confirmed by the fall in deflection. There is nothing unusual shown by the results except for the conflicting results which occur and coincide with the contradictory figures given by the transverse test-pieces. Here, again, further experiments need to be carried out before any decision can be arrived at.

Summary.

The results show fairly conclusively that phosphorus in cast iron gives rise to an extended range of solidification, and in this way becomes responsible for defects such as drawn holes and sponginess in castings of varying sectional thicknesses. A limitation of its presence to under 0·30% has a very beneficial effect upon the soundness of the resulting castings.

When considering the balance and effect of total carbon and silicon in a mixture of cast iron, it becomes of utmost importance to take into account the percentage of phosphorus present in the mixture.

Specific Gravity.—A round bar of the following dimensions was cast: Base 2¼ in., top 2¼ in. diameter and 4 in. deep. Cast in a green sand mould. Top rim, half runner on edge and half run off on the opposite edge. The blocks well cleared, then weighed in water and air in the usual manner.

Analysis.						Specific Gravity.
T.C.	Si.	Mn.	S.	P.	Cr.	
3·36	2·10	0·70	0·086	0·070	0·27	7·21
3·30	2·24	0·75	0·090	0·230	0·34	7·25
3·30	2·20	0·72	0·088	0·380	0·32	7·24
3·27	2·22	0·72	0·086	0·660	0·33	7·24
3·30	2·10	0·70	0·088	0·840	0·27	7·22
3·36	2·10	0·70	0·086	0·930	0·25	6·64

The Use of Small Roll Diameters and Development of Multiple and Roll Mills.

Dr. W. Rohn has drawn our attention to some misprints which have inexplicably occurred in his article published in the December issue of this journal. On page 47, right column and 8th line down, it should read "Figs. 4 and 6." On page 48, the paragraph in the left column commencing "With a roll diameter of 30 mm.," it is obvious that the rolling speed is 45 m. to 50 m. per minute and not 45 to 50 mm., as the English equivalent in feet is given for that speed. Again, the top line in the right-hand column should read "40 mm. wide strip rolled at 10 m. per min." instead of at 10 mm. per min.

Another New Blast-Furnace Started in Russia.

Ten blast-furnaces have been opened in the U.S.S.R. during the year 1932. The tenth one, which is the third blast-furnace in the Kossagorskaia Savod Plant, near Moscow, started working a few days ago. It is the largest of its kind for the making of pig iron from brown iron ore, and has a general capacity of 697 cubic metres, its full height reaching 27 metres.

It is of interest to note the progress in total output from the Kossagorskaia Savod plant:—In 1914 this amounted to 41,000 tons of pig iron; in 1926 to 54,000 tons; while in 1931 over 115,000 tons were produced, and it is estimated that the record output of 219,000 tons of pig iron will be reached in 1933.

Greenwood & Batley, Ltd., Albion Works, Leeds, we are informed, have taken over the goodwill, drawings, and patterns of Messrs. John Hands & Sons, Ltd. of Birmingham.

The Protection of Iron and Steel from Corrosion

By Ernest S. Hedges, D.Sc., Ph.D.

Practical Methods of Protection

SOME of the reactions which have been described in Part I.* in discussing the scientific principles of protection are utilised directly for the production of protective coatings on iron and steel, although in certain cases these serve more for the purpose of decoration than as a serious preventive of corrosion. In other cases, oxide films and other films of a like nature are applied as a basis for a coating of paint, which adheres better to the treated surface than to an ordinary steel surface. On the whole, coatings of iron compounds have not such lasting protective qualities in service as are obtained by applying coatings of other metals to the iron, nor is their useful range of conditions so wide. The principles of protection are the same, whether the protective film is an oxide, another metal, or a paint or enamel.

Oxide and Other Films.

Numerous processes are in vogue for reducing corrosion by producing a uniform film of oxide over the surface of the iron, and among these may be mentioned a process to which reference was made in Part I., which consists in adding an inhibitive chemical to feed waters. These agents are alkaline or oxidising solutions, and produce a protective, invisible oxide film at the surface of the iron, which is thus rendered passive in the way already discussed.

The "blueing" of iron may be effected by various oxidising means, such as by heating in the air or by dipping in fused potassium nitrate, but the oxide film produced thereby is not very protective unless afterwards incorporated with oil. The Bower-Barff process produces a protective coating of magnetic iron oxide by exposing the iron articles to superheated steam at 900° C., and afterwards to coal-gas. Other methods employ fused nitre baths or boiling solutions of alkaline oxidising agents. Anodic treatment in alkali is also recommended.

Recently, casehardening by nitrogen has developed. The steel is heated in ammonia, or, in another process, in fused potassium cyanide, and acquires a surface film of nitride, which, although added for the purpose of producing a very hard surface, also has protective properties. The action may be considered as a cementation, a general process which will be described below.

The coslettising process consists in immersing iron articles in a solution of phosphoric acid saturated with ferrous phosphate. The phosphate film formed is very protective, even when quite thin, and has a slate colour. It is not particularly ornamental, but when covered with a layer of enamel offers remarkably good protection to atmospheric corrosion.

The stainless chromium steels must be mentioned here, because although the protection is not confined to the surface, there now seems to be no doubt that chromium steels owe their freedom from corrosion to the extraordinarily resistant character of the oxide film which forms at the surface (see, for example, Carpenter.[1]) The protective film forms by atmospheric oxidation, and is therefore repaired whenever destroyed. Chromium becomes passive more readily than iron. Most of the non-corroding alloys contain chromium, nickel, cobalt, or aluminium, all of which are metals which readily become passive through the acquisition of a film of oxide.

Protection by Metallic Coatings.

The coating of iron by zinc must be distinguished from other metallic coatings ordinarily used. The protection afforded by zinc is electro-chemical, for in the presence of a film of electrolyte solution the zinc becomes the anode of a zinc-iron couple and corrodes, whilst the iron becomes cathodic. Exposed iron parts of small areas are therefore relatively free from attack, and the presence of small perforations in a protective film of this type is not a very serious matter, because the "protective" layer is the layer which corrodes preferentially. The same considerations hold for cadmium coatings, which, however, have comparatively little application. On the other hand, when the protecting metal is more noble than iron, as in the case of copper or nickel coatings, the electro-chemical effect is reversed, and the protection afforded is purely mechanical, like that of a coat of paint. Such metallic films act by excluding the corrosive agencies from the surface of the iron and are effective only so long as they completely cover the surface. Exposed surfaces of iron become anodic to the adjacent protective metal, and corrode more quickly than would unprotected iron. Where small areas are left unprotected, partial or complete perforation of the metal may eventually occur.

Naturally, protective metallic films are not resistant to all types of corrosion, and some are found useful only for special purposes. Economic and other considerations also enter into the choice of a protective metallic film, and among these are the mechanical properties of the coating metal, ability to undergo deformation without peeling, adherence to the iron base, resistance to abrasion, brightness and general appearance, and paint-holding properties.

Thorough cleaning of the iron surface, especially from grease and oxide scale, is a very necessary preliminary to the production of a uniformly adherent film of metal by any process. Grease is often removed by carbon tetrachloride or other solvent, or by treatment with alkali solutions. Wire-brushing, sand-blasting, and other mechanical methods are often used to remove iron scale, but the most usual method is "pickling," which consists of immersing the iron articles in an acid solution which loosens the scale without seriously attacking the metal.

* *Hedges, Metallurgia, No.* 33, 1932, *pp.* 87-89.

1 *J. Roy. Soc. Arts*, May 8, 1931.

Hot-Dipping.

The hot-dipping process consists in dipping the article to be coated in a bath of molten metal and removing it with its adherent film. It is the oldest method, and is now the basis of a very large industry, the process being most suitable for metals of low melting point, such as zinc, tin, and lead. An essential feature is the alloying of the molten metal with the base metal, for this ensures uniformity of the film, in just the same way that a stick of a soluble salt when dipped in water is withdrawn with a thin, uniformly adherent film of water, whilst a stick of sulphur or similar insoluble material retains droplets of water, which can readily be shaken off. Where no alloy is formed between the two metals, hot-dipping may often be successful by adding to the bath a metal which alloys with both. An alloy layer diminishes the tendency of the coating to draw away from the base, but, on the other hand, the alloy is more brittle than the pure metal, and the coating does not easily withstand deformation.

It is difficult to regulate the thickness of hot-dipped coatings. In the case of wire or sheet products, which are passed mechanically through the bath, the excess of the coating can be wiped off by rollers or asbestos wipers, but this is not generally possible with irregularly-shaped articles, which are dipped by hand. In such cases the excess of molten metal is sometimes removed by centrifuging.

At the temperature of the bath the base metal may undergo annealing, with consequent change in its mechanical properties, and the hot-dipping process is not suitable, therefore, for coating articles such as springs.

Electroplating.

The electrodeposition of most metals which are more noble than hydrogen can be conducted with ease, but the process is difficult or impossible with the reactive metals. An outstanding example of this difficulty is given by aluminium, which, unfortunately, cannot be deposited from aqueous solutions. The electrodeposition of zinc is made possible by the high overpotential of hydrogen at a surface of zinc.

The thickness of electrodeposited films can be regulated with exactitude even where the thinnest coating is to be given and, apart from this advantage, the base metal is not heated and its mechanical properties are not thereby spoiled. In some cases, however, iron and steel are rendered brittle by the absorption of cathodically produced hydrogen, but this is remedied by subsequent gentle heating. From the practical point of view the same electroplating installation can be adapted with very slight changes to the deposition of any metal ordinarily desired.

A smooth, hard, and compact deposit, which adheres firmly to the underlying metal, is aimed at, and much research has been directed towards defining the conditions under which such deposits may be obtained. Otherwise, the metal may be deposited in the form of large crystals or arborescent growths at isolated spots on the cathode, or it may be deposited fairly uniformly in a porous, spongy form, which is quite unsuitable for protective purposes. Porous deposits in many cases are caused by the inclusion of hydroxide in the precipitated metal: this occurs most readily at high current densities, and when the electrolyte is a neutral solution. The evolution of hydrogen at the cathode under these conditions causes the solution in the immediate vicinity to become rich in hydroxylions, which react with the metal salt to form the hydroxide. By stirring the solution, through rotating the cathode, the metal ions are supplied to the cathode at a greater rate, and a higher current density can be employed without loss of current efficiency and with an improvement in the deposit. Excellent deposits, entirely free from sponge, are usually obtained in the electrolysis of complex cyanide solutions.

The hardness of electro-deposited metals is a particularly important property, and a study of the conditions influencing the hardness was made by Macnaughtan,[2] who measured the Brinell hardness of iron, nickel, cobalt, and copper deposited electrolytically under various conditions. An increase in hardness was caused by (1) lowering of temperature; (2) increase of current density; (3) decrease of metal-ion concentration; and (4) increase of hydrogen-ion concentration. These conditions correspond with those which favour small crystal size. There is, therefore, a close parallelism between hardness of the deposit and the size of grain.

Although the mean thickness of electrodeposits is easily controlled by the density and duration of the current, uniformity of thickness of the film is obtained only by taking special precautions, for the current density is not evenly distributed over the surface of an electrode, the current lines converging in the direction of the oppositely charged electrode, and tending to concentrate at the corners and edges of irregularly-shaped articles. In practice, a proper spacing of the anodes serves to counteract the uneven distribution of current density and when possible the articles forming the cathode are kept moving. A serious matter is that recesses in the article may escape with only a very thin coating, and in this respect solutions of different salts of the same metal differ considerably. This behaviour of solutions is termed their "throwing power"; the throwing power of complex cyanide solutions is particularly high.

Small articles may be placed in a perforated barrel, made of non-conducting material, which is immersed in the electrolyte solution. The articles form the cathode of the cell, and are in contact with flexible metallic conductors on the inside of the barrel. The barrel is supported horizontally, and can be rotated during the electrolysis, so that the articles tumble about and continually expose new surfaces to be plated. In another process, the articles are hung on to a chain conveyer, which is moved through the solution and passes between the anodes. The conveyer and the suspended articles form the cathode of the cell. The zinc coating of wire, wire-netting, etc., is made continuous, the wire passing in turn through pickling and washing tanks, the plating bath, and final washing tanks.

Metal Spraying.

The application of thin metallic films to structures of iron and steel by spraying the molten metal was developed by Schoop[3] in 1910. The apparatus consists of a "pistol," which can be held in the hand and directed towards the surface to be covered. In the pistol the metal in the form of wire is fed continuously to an oxy-hydrogen or oxy-acetylene blowpipe flame, in which it is melted and blown in the form of a fine spray by means of a blast of air or inert gas. An electric form of pistol has also been devised, in which the metal is melted in an electric arc formed between two wires, and the molten metal is projected by means of an air-blast.

Metal spraying has two great advantages in that the film may be applied to structures *in situ*, and may be applied at any desired spot. The thickness of the deposit is controllable between fairly narrow limits. The process is, morever, particularly suitable for "touching up" coatings which have been applied by other methods. Thorough cleaning of the surface to be coated is essential, and sand-blasting has proved to be the best method, as it roughens the surface and gives a better hold to the film.

Microscopical examination[4] of the structure of very thin, sprayed metal films recalls the effect produced by the splashing of rain-drops against a window-pane, each "splash" solidifying on impact. The thicker films consist of overlapping scales. The film generally has a laminated

2 *J. Iron and Steel Inst.*, 1924, 109, 409.
3 *Rev. Met.*, 1910, 7, 585.
4 Turner and Ballard, *J. Inst. Metals*, 1924, 32, 291.

structure, caused by the surface oxidation of each metallic particle, which reduces the coherence of the scales and renders the coating somewhat porous. This porosity is reduced by using a blast of an inert gas. Subsequent polishing also reduces the porosity and makes the metal denser, thus increasing the protective qualities of the film and improving the appearance of the finished article. No evidence of the existence of an alloy layer at the surface of the base metal has been obtained, and the adherence of the film is probably purely mechanical.

Cementation.

Cementation consists in producing an alloy at the surface of the metal. The articles are packed in the powdered coating metal in a drum which can be rotated and which is heated at a temperature somewhat below the melting point of the more fusible metal, when diffusion of the coating metal into the base metal occurs and an alloy layer is formed. The process is restricted to metals which are capable of forming alloys, and there are three important commercial applications to the protection of iron, known respectively as "sherardising" "chromising" and "calorising." These are described below. The coating produced in each case is essentially an alloy, and is more brittle than a pure metallic coating. The cementation process is not a good method, therefore, for the protection of articles which have to wthstand deformation in service.

Zinc Coatings.

Relatively thick coatings of zinc, suitable for withstanding outdoor corrosion, are applied by the hot-dipping process. An iron container is used, containing molten zinc kept at about 450° C. The temperature depends on the nature of the material to be coated, for the higher the temperature the greater is the solvent action of the molten zinc on the walls of the container and the greater is its alloying action at the surface of the iron articles being dipped. The surface of the molten zinc is covered with a flux, which consists of ammonium chloride with some tallow and occasionally glycerol. The flux cleans the metal, removes moisture, and prevents oxidation of the surface layer of zinc.

A dross, consisting of an iron-zinc alloy, gradually accumulates in the bath and is removed at intervals. In many cases, lead is added to the bath ; it forms a separate liquid layer at the bottom and provides a cushion on which the dross floats, so facilitating its removal ; lead also has the effect of preventing the overheating of the bottom of the container and diminishing the attack of the molten zinc on the iron.

Aluminium in the form of an aluminium-zinc alloy is sometimes added. It makes the contents of the bath more fluid and provides a thinner and more uniform coating, and is therefore particularly useful when the articles to be coated are of very irregular shape or contain crevices. The addition of 1% of tin is also recommended for increasing the uniformity of the coating.

The addition agents also influence the characteristic "spangle" effect of hot-dipped zinc coatings. The spangles are much admired, and are in general demand, but the appearance of a spangled coating is probably its best recomendation. There is evidence that the zinc film is particularly thin near the margins of large spangles.

The structure of the coating is by no means simple, for it consists of at least two and sometimes three distinct layers. Next to the base metal, there is a layer consisting mainly of the intermetallic compound $FeZn_3$, then comes an intermediate layer, consisting largely of the compound $FeZn_7$, and the outer layer is mainly zinc, saturated with iron. The alloy layer is particularly thick when the dipping is carried out slowly. The alloys are anodic to iron, and therefore assist in protecting the base metal, but in this respect they are inferior to pure zinc.

Electrodeposited zinc coatings are simpler than those obtained by hot-dipping. They consist of a single layer of pure zinc, and if any alloying occurs with the base metal the thickness of the alloy layer can be only of molecular dimensions. The average composition is 99·85–99·90% of zinc, with metallic and other inclusions depending on the nature of the anodes and any addition agents used. The mechanical properties are good, through the absence of an alloy layer, and the adherence of the coating to the base metal is very satisfactory. The uniformity and purity of the deposit ensure good protection, but electrodeposited zinc coatings are generally used for articles requiring a thin coating. The thicker coating obtained by hot-dipping is more usually applied for withstanding severe corrosion.

Zinc spraying is used for coating towers for bearing overhead cables and other aerial structures, for bridges, hulls of ships, and other large-scale iron and steel structures, where there is the advantage that the coat can be renewed without dismantling the material.

Sherardising is the cementation of iron by means of zinc. The coating is obtained by packing the iron articles loosely in a drum partly filled with zinc dust containing some zinc oxide, which is rotated for some hours at 350°–375° C., the temperature being maintained by electric heating coils in the drum. The film is essentially an iron-zinc alloy, and the average thickness is about 0·0025 in. When the temperature is higher or the duration of cementation longer a second alloy layer appears between the outer coating and the base metal, and it is probable that this consists of the compound $FeZn_3$.

The protection afforded by the zinc-iron alloy is electrochemical, like that of zinc. During weathering, both the iron and the zinc constituents of the alloy undergo oxidation, and in films of low iron content a dark-grey or black film of the mixed oxides forms on the surface. This oxide film has protective properties, and such sherardised materials are therefore resistant. When, however, the iron content of the alloy rises to about 15% the resistance of the coating to atmospheric corrosion is very low. In this case the product of oxidation is a red, loosely adherent powder, which offers no protection to the underlying metal. The use of a poor quality of zinc dust, rich in iron, leads to the mechanical inclusion of particles of iron in the outer coating, and rusting then occurs readily on weathering.

Tin Coatings.

Tin possesses special chemical and mechanical advantages as a protective film, for it can withstand serious deformation without damage, and the metal is very resistant to corrosion. The absence of toxic properties is another important point which has led to its use for lining containers of foodstuffs. The hot-dipping process is the most useful method of tinning iron. The essential features are similar to those described for zinc, a bath of molten tin being kept at about 300° C. and covered with a layer of palm oil.

The film of tin on the containers used for foodstuffs is usually only about 0·0003 cm. thick. The tin used is generally of high purity and other metals are not added to the bath as a rule. The sheets are not spangled after hot-dipping, but for ornamental purposes the spangles may be produced by subsequent etching with dilute hydrochloric acid.

The continuity of the film is very important, for tin is normally cathodic to iron and exposed iron surfaces may corrode rapidly. Tinned iron sheet has a serious defect in the existence of minute perforations in the film of tin. The number of such perforations per unit area does not decrease in proportion to the thickness of the film, and the evil is not readily overcome in consequence. There is some evidence that the perforations are caused by hydrogen retained by the iron after the pickling process, which is evolved at the temperature of the tin bath, with rupture of the film of molten metal. This pinhole effect is perhaps not so serious a matter in the canning of foodstuffs as was at one time feared. The recent report of

Morris and Bryan[5] on the corrosion of the tinplate container by food products, shows that when the tin-iron couple is immersed in acid solutions of fruit juices the tin, which is initially the cathode, soon becomes the anode, whilst the iron becomes passive and receives cathodic protection. The corrosive attack is spread over a large surface of tin, therefore, rather than concentrated at minute areas of exposed iron, which would undoubtedly soon become pierced.

Tin is not deposited electrolytically on iron to an extensive degree. Electro-deposited tin films are dull in appearance and require subsequent polishing. The principle of the short-circuited electrolytic cell is employed in the tin-plating of safety-pins, buckles, and other small articles. The articles are placed in contact with sheets of tin in an electrolyte consisting of a hot solution of sodium chloride and alum. A difference of potential is set up, the tin becoming the anode of the cell and dissolving, being subsequently precipitated on the steel articles forming the cathode. The deposition of tin is limited by the fact that as soon as the surface of the steel article becomes covered with tin the electrolytic couple no longer exists, and the process automatically comes to an end. The coating produced is therefore very thin and uniform; in brightness it exceeds the film deposited by the ordinary electrolytic method.

Lead Coatings.

Lead coatings cannot be applied successfully to iron by hot-dipping, because no alloy layer is formed at the surface, but the process can be carried out by adding to the bath some tin or antimony, or both, which are capable of alloying with the base metal and with the coating metal. Lead may be deposited electrolytically from fluosilicate, fluoborate, and perchlorate solutions with the addition of glue or other organic colloid to assist in the deposition of a dense coating. The properties of the coating may afterwards be improved by slightly working the surface. The spraying process is also very serviceable in the production of lead coatings.

Lead coatings have the advantage of comparative immunity to attack by sulphuric and sulphurous acid fumes and are therefore particularly useful in the lining of flues and in all situations where iron or steel structures have to be exposed to these vapours or fumes. In addition, lead films possess excellent mechanical properties for material which has to undergo deformation, and they serve as an exceedingly good basis for a coating of paint.

Nickel Coatings.

Nickel coatings are made electrolytically from a slightly acid solution of nickel sulphate, and although the deposit may be made directly on steel, it is often considered desirable to give a preliminary thin coating of copper or of cadmium. Sometimes three layers are deposited in the order nickel, copper, nickel.

The film as usually applied has a thickness of about 0·0003 in., and parts subject to wear are liable to expose the underlying metal in time. Such parts will soon show signs of rusting, because nickel is cathodic to iron. Another feature leading to the failure of nickel coatings is that they are often deposited in a state of internal stress, so that if a break once appears the coating may peel off in the form of rolls. Nickel deposits are characterised by the exceedingly small size of the grains.

Copper Coatings.

A solution of the double cyanide of copper and potassium is used for electroplating iron with copper, for the spongy deposit which forms when iron is immersed in simple cupric salt solutions prevents the adherence of the electro-deposited film. The deposits from cyanide solutions are exceptionally finely grained. Copper coatings have not received much application as a preventive of corrosion. They are unable to retain a high polish and the surface tarnishes readily. The electrodeposition of thin films of copper has an important applicaton in the casehardening of steel parts. The portions so covered remain soft after the treatment, because the carburising gas does not penetrate the copper film.

Chromium Coatings.

The great popularity of chromium coatings is due partly to their ability to take a high polish and retain it even under severe conditions of corrosion, and partly to the hardness of the metal, enabling the surface to withstand abrasion to an exceptional degree.

Chromium readily assumes the passive state in the air, becoming covered with a very resistant film of oxide, and the protection afforded is mainly due to this oxide film. Thus, we have a striking case of how the efficacy of an artificially applied metallic film depends on the existence of a spontaneously acquired oxide film at its surface. Chromium plating is particularly useful for service at high temperatures, because the oxide film effectively prevents further oxidation, and it has found application in the glass and ceramic industries. It is also particularly resistant to attack by sulphur and sulphurous compounds, thereby supplying another branch of industries with a resistant material.

Chromium plating is deposited electrolytically from solution of chromic acid containing a little chromium sulphate, using anodes of the insoluble type, such as lead. A drawback is that the deposit is porous, and the coating may fail unless it is fairly thick. It is more usual, therefore, first to give a coating of nickel, or copper, or both, and to cover the undercoating with a thin film of chromium, which provides a lustrous finish and freedom from surface tarnish.

A cementation process known as "chromising" would probably have received greater application than it has at present if the electrolytic process had not been developed so satisfactorily during recent years. This process is essentially similar to sherardising, the articles being packed in a mixture of chromium powder with powdered aluminium oxide, which acts as a diluent. The temperature used is 1,300–1,400° C., and oxygen and water vapour must be excluded. An inert atmosphere, generally hydrogen, is used. A chromised surface can readily be polished, and is not so hard as electroplated chromium surfaces. Chromised coatings are particularly resistant to attack by dilute nitric acid, but are not resistant to hydrochloric acid.

Aluminium Coatings.

Aluminium alloys so readily with iron that a direct hot-dipping process is not very successful, and the surface skin of oxide, which forms very readily, tends to interfere. Aluminium cannot be deposited electrolytically from aqueous solutions, and the only method of applying a coat of *pure* aluminium is by the spraying process.

Cementation by means of aluminium is known as "calorising," and can be carried out by heating the articles in a mixture of powdered aluminium and aluminium oxide. At the present time, it is more usual to perform the process in two stages, the metal being first hot-dipped in a bath of molten aluminium and subsequently heated, whereupon the aluminium diffuses into the base metal and the final result is similar to that obtained by the ordinary, direct cementation process. The calorised coating is designed especially for service at high temperatures, where the aluminium acquires a resistant superficial film of oxide, which protects the article from further oxidation. Up to 900° C. the life of the coating is almost unlimited, but at higher temperatures the diffusion of aluminium into the interior of the metal becomes a serious matter. This coating also has the advantage of being resistant to attack by sulphurous fumes.

5 *Dept. of Scientific and Industrial Research. Food Investigation Special Report* No. 40; 1931, H.M. Stationery Office.

Recent Developments in Tools and Equipment

A NEW DESIGN OF CRANK SHAPER.

ALTHOUGH production methods alter from time to time and the shaper is frequently relegated in favour of other types of machines, it is remarkable how it reclaims its place in modern machine shops and not infrequently supplants more expensive machines. It is not really surprising, because the shaper is a really useful and inexpensive unit. It requires comparatively little skill to operate and the cost of upkeep and cutting tools is remarkably low in comparison with other types of machine tools. Many designs are capable of heavy cutting, and will produce accurate work. The popularity of this type of machine is largely due to development made by the Butler Machine Tool Co., Ltd., of Halifax, who have produced shapers over a period of fifty years. Their long experience has enabled them to design and produce machines of great refinement and finish, in which careful attention is given to every detail to ensure facility of operation and lasting service. The new design shaper illustrated in Fig. 1 is the latest development in crank-shaping machines manufactured by this firm, and it offers new features in design which combine to make it a machine tool of considerable value.

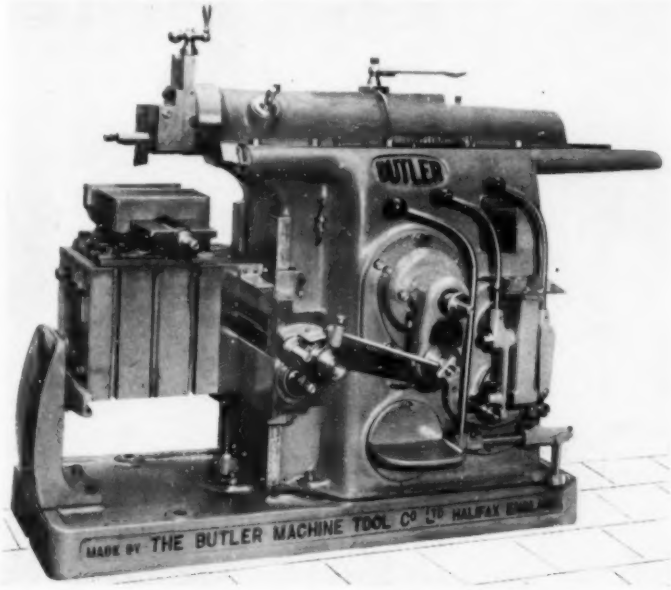


Fig. 1.—Front side view of machine.

The body casting is of rigid construction, the front side being of buttress shape, strongly ribbed inside, in order to approximate as nearly as possible to a double-walled casting. This feature is important, as this side of the machine has to withstand all the strain and twist of the drive when cutting. The base is designed to avoid any tendency to deflect at the front, while the ram is of greater depth than previous models, the section of the vee slides being also increased.

The saddle is of greater length, while machined tee slots in the apron have been discarded in favour of four short cast tee slots, in order to prevent distortion when securing the table. The table-securing bolts have been brought to the front, giving increased rigidity and support. The table support is of improved design, being protected against dirt and self-adjusting to the position of the table.

The drive to the machine is by belt to a single friction-clutch pulley, thence through a four-speed gearbox and double gear, giving eight speeds, ranging from 10 to 120 cycles per min. The four-speed gearbox and double gear, illustrated in Fig. 2, are manufactured as a unit, the gears being of heat-treated nickel-chrome steel. All sliding gears are carried on a single six-splined shaft, whilst all shafts are mounted on ball bearings. The single helical stroke wheel shown in Fig. 3 is of new design, giving increased bearing surface in the body. This is obtained by incorporating a large-diameter phosphor-bronze-bushed bearing in the stroke-wheel, which *revolves round a fixed bearing* in the body instead of revolving in a spindle bearing of small diameter.

A further new departure in the drive for which a patent is pending is the link motion shown in Fig. 4. Instead of the usual small pivot at the bottom of the link, a large-diameter trunnion acts as a pivot, and also has a large hole bored across its axis. The link has a round shank at the lower end which is a sliding fit in this cross hole, thus allowing the upper end to follow a straight line and be attached directly to the ram. By this means the usual connecting rod between the link and the ram is avoided, and two troublesome pin joints eliminated. Further, the link itself is suspended freely from the ram instead of being poised on a small pivot. The trunnion mounting is not constrained sideways, and the link is therefore free to find its own centre, and is not subjected to twisting strains. This new link drive has proved to be of great importance in reciprocating machine tools, as it enables much higher speeds to be used and maintained, and increases the cutting efficiency.

Fig. 4.—Patented stroke link, trunnion mounting and ram.

The machine is lubricated from a gear pump, the oil being contained in a sump in the base. The oil is circulated to all working parts of the machine, the cascade system being used for the gearing and the trunnion mounting for the link. Oil is also pumped into wells in the ram strips, the flow to the vees being regulated by a wick feed, and up the link and on to the phosphor-bronze stroke die and top pin joint.

The horizontal and vertical feed is operated from a slotted disc and ratchet wheel, the table feed screw having

two leads and ball thrust bearings at each end. Six ratios of feed are available from 6 to 72 cuts per inch.

The control levers have been grouped as near as possible to the working position. The two gear levers work in a simple gate-change cut in a flat steel plate, this plate being chromium plated and engraved with the available cycles. The starting lever also actuates a quick-acting brake for instantly arresting the ram in any position.

Bearing slides have been covered wherever possible, a substantial guard being fitted at the rear of the machine to protect the ram slides, while felt wipers are fitted at the front. The table slides have also been protected as far as possible by covers and wipers. A swivelling or combined swivelling and tilting table can be fitted according to requirements. The combined table can be swivelled through 360°, and the built-in table top tilted to a maximum of 15°. These shapers are available as belt-driven or motor-driven machines in a range of sizes.

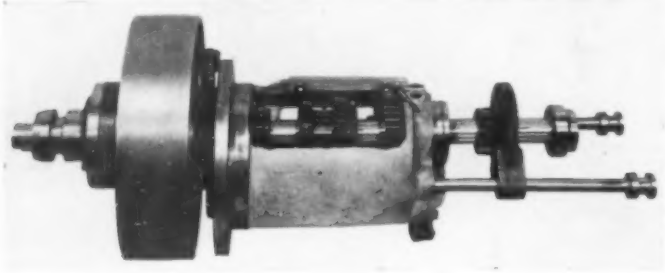


Fig. 2.—Four-speed gearbox and double gear.

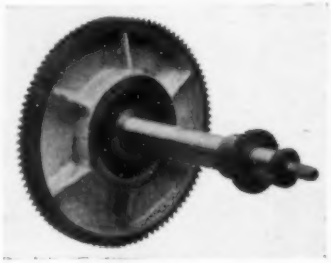


Fig. 3.—Single helical stroke wheel.

High Quality Finish on Rolled Sections

(*Continued from page 78.*)

finish is desired. A very successful method is employed by Barrow Hematite Steel Co., Ltd., which produces a sheen on the rolled material almost comparable to a polished surface. This is plainly visible in Fig. 1, which shows a number of rolled sections on the cooling bed shortly after being rolled.

The mill (Fig. 2) in which these sections were rolled is a 12 in. Double Duo, constructed by the Brightside Foundry Engineering Co., Ltd. The equipment consists of five stands of roll housings and two stands of pinion housings, driven from opposite ends on the mill train by two 400-h.p. variable-speed motors through a combined reduction gear and diagonal gear set, one motor driving two stands of rolls and the other motor five stands of rolls, the maximum speed of the rolls being 190 r.p.m. A line drawing showing the layout of this mill is shown in Fig. 3.

In each stand adjustable equipment is fitted to remove scale from the material before it enters the rolls, but in order that this can be effected successfully, considerable attention is given to the rolling temperature of the material, which should be under adequate control. The temperature varies with the type of steel, but for the best surface finish the final rolling operation is delayed until the temperature is such that the scale is loose and is readily removed by the special apparatus provided.

The furnaces in which the billets are heated prior to rolling embrace the Stein system of recuperation, and were built by Stein and Atkinson, Ltd. They are of the natural draft type, in which the air for combustion passes up through a large number of vertical passages of small section and the waste gases pass horizontally and in a zigzag manner downwards through flues formed between the recuperator blocks. In this way the air picks up heat from the waste gases and enters the combustion chamber in a preheated condition. The whole of the combustion air is preheated in this way, and the amount is controlled by adjustable air-inlet valves. A reducing atmosphere in the working chamber of the furnace is readily obtained by reducing the air supply until there is a slight insufficiency for complete combustion of the gas. These furnaces supply the billets at the required temperature, and Fig. 4 shows a billet being drawn for rolling the sections previously illustrated.

A critical examination of a wide range of sections and spring plates produced by Barrow Hematite Steel Co. indicated a degree of finish comparable in many cases with machined surfaces. This applies to both carbon and alloy steels, which were viewed. It should be remembered, however, that a very high finish increases the cost of production and should only be asked for by the user when the articles for which the sections are required are to be given a subsequent finish. The relation between the degree of rolling finish and the cost of sections can be fixed more satisfactorily by co-operation between the producer and user; certainly much work in manufacturing from sections can be eliminated by making full use of modern technique in obtaining sections of high finish.

Catalogues and Other Publications.

Expert information on the applications of gas-fired conveyer ovens to the work of drying various types of enamels, lacquers, and varnishes is contained in No. 226 of "A Thousand and One Uses for Gas." The design and choice of ovens; the effects of stoving on various constituents and on different types of finishes; and the advantages of gas—simplicity, reliability, and economy—are among the subjects treated at length. The issue is illustrated with excellent photographs of installations at various works. Copies may be obtained from the Secretary, the British Commercial Gas Association, 28, Grosvenor Gardens, S.W. 1.

We have received a copy of the first issue of the *Craven Machine Tool Gazette*, which is to be published quarterly. It deals primarily with the activities of Craven Brothers (Manchester), Ltd., and also contains items of topical and general interest to the engineering trade generally. Through this *Gazette* this firm will advise their friends of the latest developments in their manufactures. Comment will be made on general development of machine-tool design, tooling and operation, and on development in other lines of engineering, and it is expected that successful engineers will contribute to its pages from time to time. It is very attractively prepared, and the editorial matter presented is both interesting and informative. Copies may be obtained from Craven Brothers (Manchester), Ltd., Reddish, Stockport, at a price of 3d. each post free or for a subscription of 1s. per annum.

Personal.

Ing.-Com. N. Al. Anguelov, a machine and metal agent of Sofia, Bulgaria, desires to communicate with British manufacturers of cheap pig iron, merchant iron, and tinned and galvanised sheets, who are seeking openings for their products in Bulgaria.

Reviews of Current Literature.

Steel and its Practical Applications.

DESPITE the limitations of space, which has necessitated considerable pruning, this book contains a remarkable amount of information. It deals with iron in its various forms, but principally in the form of steel. It is doubtful whether any material shows such wide variation in mechanical properties as a result of slight variation in chemical composition as steel. Even when the chemical composition remains unaltered, the effect of mechanical operations and heat-treatments transforms the steel into a material which is entirely different from its original condition. It is only necessary to appreciate the difference between an ingot and wire produced from it to recognise the remarkable effect work and heat-treatment have upon this material.

The authors have wisely refrained from attempting to give a complete account of the variation of chemical, physical, and mechanical properties over the remarkably wide range of which steel is capable, if this were possible, but a surprising amount of information is presented on what may be regarded as essential to those who desire a knowledge of steel. Properly manipulated, the ferrous alloys are invaluable to mankind, and they may be applied to innumerable uses, but their success depends upon the mechanical and thermal treatment to which they are subjected in the various production processes. Careless or ignorant workmanship, either in the manufacture of the steel or in its subsequent treatment, will reduce its value and be a source of danger because of the detrimental influence on its mechanical properties.

We note a statement by the authors that the microscope was first adapted to the study of metals by Sorby, 1887. In the revised edition of the work by Sir W. C. Roberts-Austin, entitled "An Introduction to the Study of Metallurgy," the statement is made that "the microscope was first applied to the examination of iron, and the first records go back to 1722, when Réaumur described the structure of a chilled casting under the microscope, and traced the changes of softened cast iron as modified by the elimination of impurities." He further stated that "Francois, as early as 1832, took the interesting case of the direct reduction of iron from its ores, and followed the successive changes by the aid of the microscope." The following passage, quoted from Francois, is of interest: "If to these analytical data observations under the microscope with a magnification of 300 to 400 diameters be added, it is seen that ordinary iron is merely a metallic network with a close-grained tissue, with submerged scoriaceous opaline, sometimes sub-crystalline, portions, and with little globules and metallic grains ranged in every direction. Sometimes nests of translucent prismatic and bascillary crystals, with metallic portions adhering, are noticed hidden in the paste. These are the grains of steel which can be made to disappear by heating." This would seem to indicate that the microscope was adapted to metallurgical investigations at an earlier date than that mentioned.

This book is, however, a very commendable effort to describe for the engineer the nature of the ferrous materials at his disposal, the processes which they must undergo to ensure their fitness for his particular requirements, and the means by which he may detect and trace to their source defects in material or workmanship. To the engineer who has little time for a fuller study of the subject this book provides him with information in a lucid and interesting manner which he should find profitable. It should also prove of considerable value to buyers of materials to whom technical knowledge is now more essential than ever before.

By WILLIAM BARR and A. J. K. HONEYMAN, B.Sc. Published by Blackie and Son, Ltd., 17, Stanhope Street, Glasgow, C. 4. Price 6s. net.

A Textbook of Metallurgical Problems.

THIS work is dedicated to the memory of Professor Joseph W. Richards, who with the publication of "Metallurgical Calculations" in 1906-1908 did much to promote the use of problems as a means of education. In general, this new work continues the methods introduced by Professor Richards, going somewhat further in certain directions, and giving new and revised data necessary for making the calculations as accurate as possible in the light of work published since the earlier work was written. Such revisions as have been made do not destroy the significance of the earlier computations, but rather improve accuracy, In most cases, however, the older data will be found to give satisfactory results for practical purposes.

The author has given particular attention to grading the work in his treatment of the subject, and the first part of the book contains much explanatory matter, with details of examples, which is almost indispensable to the student in metallurgical engineering. With increasing knowledge and experience the student is presented with problems of increasing difficulty, in which explanations are purposely curtailed. Care has certainly been exercised in an endeavour to secure a proper balance between the task set the student and the guidance afforded him in accomplishing it, and despite difficulties, which every teacher of the subject will appreciate, this has been effected admirably.

The majority of the problems, which are given at intervals throughout the book for solution by the student, are intended to involve from one to three hours of student time in their solution, but shorter problems suitable for examinations are also included. Many of the problems are taken from actual data from particular metallurgical plants with a view to adding interest. The author is Associate Professor of Metallurgy at Lehigh University, and is associated with others in teaching metallurgical problems, not only to students studying metallurgical engineering, but also to students in practically every other branch of the engineerng industry. Although only part of the work covered in this book would, in many cases, be considered within the scope of their training, there can be no doubt that the broad field covered has a considerable value to them in applying fundamental principles to such metallurgical problems as they encounter.

Most of the problems given involve a series of steps which the student must pursue in accordance with the given data. Each step in itself is relatively simple, but the extended reasoning necessary constitutes a difficulty that is of value. These problems are particularly useful as a form of instruction in metallurgical principles and processes; they emphasise the quantitative side of the subject, and tend to make what may be looked upon as abstruse questions more practical; they also cause the student to give more thought to the subject than would otherwise be generally given.

In a valuable work of this character it would seem profitable to include a chapter on some metallurgical problems awaiting solution, with a view to indicating possible fields for research. This, of course, is only a suggestion, and does not in any way reflect on the value of this book, which can be regarded as the best textbook on metallurgical problems we have seen. Its value lies primarily in the method of presenting and clarifying the underlying principles involved and in guiding the student in the solution of problems which so frequently arise in the various branches of engineering.

We have no hesitation in recommending this book to all students who are studying engineering, in the curriculum of which metallurgical subjects form a part. Certainly it should be available to teachers of engineering subjects as a textbook for reference purposes. It contains 425 pages, possesses a useful index, is admirably produced, and reflects credit on the publishers as well as the author.

By ALLISON BUTTS, A.B., B.Sc. Published by McGraw-Hill Publishing Co., Ltd., Aldwych House, London, W.C. 2. Price 24s. net.

Journal of the Institute of Metals.

Vol. XLIX. "Proceedings."

THE latest volume of the Institute of Metals Proceedings is of unusual interest if only because it contains a record of the recent joint meeting of the Institute of Metals with the Iron and Steel Institute. As a result of the kind invitation of the American Iron and Steel Institute and the American Institute of Mining and Metallurgical Engineers, it was originally intended to hold this joint meeting in America. Unfortunately, circumstances prevented the fulfilment of this plan, but it led to the joint meeting being held in London, which further cemented the good feeling existing between both Institutes.

All the communications made to the Institute of Metals at this September meeting are reproduced in full in this volume, together with the discussions. The papers presented cover a wide and practical field, as is indicated by such titles as "Mould Materials for Non-ferrous Strip Ingot Castings," "Mechanical Properties of Nickel Wires," "Attempts at Making Beryllium-Magnesium Alloys, "Modern Works Plant and Equipment for the Hot-working of Nickel and Nickel Alloys," and "Properties of Commercial Varieties of Copper at High Temperatures." By far the most extensive contribution is Dr. H. J. Gough's 76-page autumn lecture on "Corrosion-Fatigue in Metals," in which almost classic dissertation the author endeavours to reduce the mechanism of corrosion-fatigue—a vitally important matter to engineers,—to an ordered sequence of chemical and physical events which are explicable in the light of existing knowledge relating to corrosion and fatigue phenomena.

The volume is well illustrated—there are 59 plates as well as scores of textual illustrations,—and the printing is good; whilst the style of binding—in green cloth with gold lettering—is uniform with that adopted since the appearance of the first issue of the journal.

Edited by G. SHAW SCOTT, M.Sc., F.C.I.S. The Institute of Metals, 36, Victoria Street, Westminster, London, S.W. 1. Price 31s. 6d.

The Heterogeneity of Steel Ingots.

THE work of the Committee on the Heterogeneity of Steel Ingots has continued since 1924, and results of its investigations have been published at intervals in the form of reports. The first and second reports presented by the Committee, in 1926 and 1928, were explanatory in character, and contained a detailed study of thirty-two ingots chosen as representative of normal practice. In addition, the second report contained a discussion on the influence of the mould upon segregation, and an indication of the influence of certain metallurgical characteristics of the steel upon its homogeneity. The third report, issued a year later, was somewhat different in character, and consisted of fundamental researches into several matters having a controlling influence upon the practical problems of the investigations. In the fourth report, which was presented at the May, 1932, meeting of the Iron and Steel Institute, and referred to the May issue of METALLURGIA, these two aspects of the work are linked together. The Committee feels, however, that the time has not yet come when an exhaustive analysis of the experimental results of the investigation, in the light of theoretical researches, can be achieved.

This report is subdivided into seven sections, the first containing records of the conditions of manufacture of a further 27 ingots and a discussion of the results of their examination. In the second section is given a brief account of the hydrogen reduction method for the determination of oxygen in steel and a discussion of the oxygen in the silicate inclusions disseminated throughout the ingot. The non-metallic silicate particles, their distribution and composition, are considered in greater detail in the third section.

A detailed study of the principles underlying the manufacture of rimming steel is given in section four, in which the Committee, as a result of the investigations, state that in the present state of knowledge no satisfying explanation of the phenomena associated with this type of ingot can be regarded as established. The report of a sub-committee appointed to study the accuracy of pyrometric measurements at steel-making temperatures is given in section five. The thermal history of several ingots during the period immediately following casting is recorded, and considerable light is thrown on the separation of the ingot from the mould and the discontinuity in the transference of heat across the ingot-mould boundary. The study of ingot moulds is elaborated in section six, from the standpoint of the physical characteristics of the mould material, while the seventh section comprises a development of the mathematical treatment of the problem of the distribution of temperature in the cooling ingot.

The experimental work carried out during the past three years proves that the presence of non-metallic particles and ghosts in the ingot is largely governed not only by the principles of manufacture, but also by the conditions of melting and refining in the furnace, the condition of the finishing slag at the moment of tapping, and the manner of addition of the deoxidants.

"Fourth Report on the Heterogeneity of Steel Ingots." 8vo. Pp. 204 with 42 Plates. Price 16s. Published by the Iron and Steel Institute, 28, Victoria Street, London, S.W. 1.

1932 A.S.T.M. Proceedings.

THE "Proceedings of the American Society for Testing Materials" is in two parts; the first volume contains the annual reports of the many Society committees and the technical papers and standards appended thereto. The annual address of the President, entitled "Research and the American Society for Testing Materials," and the report of the Executive Committee are also included.

The reports of the Standing, Research and Sectional Committees which function in both ferrous and non-ferrous metals fields cover a wide range of activities, while the papers, which are appended to the reports, are very comprehensive in character and indicate thoroughness in the study of the various subjects.

The second volume includes the many technical papers presented at the annual meeting and the discussions which resulted. By including the extensive oral and written discussions of the papers, there is retained in permanent form the views of many technologists on the subjects. Often additional data are given, and those, with various views presented, clear up points on which there are uncertainties. This is one of the real values of these "Proceedings." The papers deal with important problems and subjects relating to the ferrous and non-ferrous metals industries, while in addition a number of papers deal with non-metallic materials. Each volume provides a fund of information. Part I. having 1,071 pages, while Part II. comprises 824 pages.

Copies of the "Proceedings" can be obtained from A.S.T.M. Headquarters, 1315, Spruce Street, Philadelphia, Pa. Prices for each part, $5.50, paper binding; $6, cloth; $7, half-leather.

Index to A.S.T.M. Standards.

DESIGNED primarily to be of service to those interested in ascertaining if the American Society for Testing Materials has issued any specifications, methods of testing, recommended practice or definitions on a specific subject in the field of engineering materials and the allied testing field, the Index of Standards and Tentative Standards, which is issued annually in December, meets an increasing demand. This Index gives, under appropriate key words, the titles of all this Society's standards, together with references to the publications in which they may be found. Each standard is indexed under the principal subjects covered by it.

Copies of this Index may be obtained without charge on application to the Offices of the Society, 1315, Spruce Street, Philadelphia, Pa., U.S.A.

Business Notes and News

Veteran Liner's Notable Performance.

That famous liner, the *Mauretania*, accomplished a remarkable performance on the voyage which registered her first arrival in New York this year. Despite severe weather, she reached New York one hour ahead of schedule. When it is appreciated that all other vessels on the west-bound trip were unable to maintain their time against continuous gales and high seas, the performance of this veteran is remarkable—all the more noteworthy by the fact that two of the ships she outpaced on the voyage were the *Bremen* and the *Leviathan*.

Her speed for the voyage from Cherbourg averaged 22.68 knots, and the total time occupied on the trip was five days 16 hours 18 minutes. At one time she had to encounter a wind velocity of 90 miles an hour. This achievement is only one of the many by the *Mauretania* which indicate that, despite her 24½ years' continuous service, she is still able to set up records.

The performance will give satisfaction to those who appreciate the value of British shipbuilding skill, as it provides proof that vessels built in this country can be depended upon to give long and efficient service.

Lancashire Steel Corporation's Developments.

The Lancashire Steel Corporation have acquired the Whitecross Company of Warrington, which manufactures a wide range of wire goods. This development is part of a scheme of rationalisation begun by the formation of the Lancashire Steel Corporation in 1930 to take over the control of the iron and steel interests of the Partington Iron and Steel Co., the Wigan Coal and Iron Co., Pearson and Knowles, Ltd., and Rylands Bros., all situated in Lancashire.

The original scheme, it will be remembered, was drawn up for the re-arrangement and consolidation of all these businesses as one manufacturing unit. It included new construction work to the extent of £1,750,000, a powerful financial group providing the necessary money. This scheme has lately been supplemented, and a further step forward has been planned and construction commenced. This consists in putting down a continuous wire rod mill, containing all the latest improvements.

With the completion of these improvements, the steel wire rods will be manufactured from start to finish on one site. Beginning with the raw materials, consisting of iron ore and coal, the process will be continuous through the manufacture of the coke and pig iron to the steel ingots, blooms and billets, and wire rods. All waste transport from one works to another will thus be eliminated, with resultant cheapening of costs.

Tyneside Firm Makes Employment.

Messrs. Swan, Hunter, Wigham Richardson, Ltd., contemplate building a new graving dock at Wallsend, and the preliminary borings and work in connection with the scheme are practically completed, when constructional work will commence. The dock is to be constructed by Sir Robert McAlpine and Co., Ltd., the well-known works contractors, who have recently been employed on a similar scheme on the Clyde for Messrs. Barclay, Curle, and Co., an associated company of Messrs. Swan, Hunter, Wigham Richardson.

It will be one of the largest on the Tyne, and will probably cost between £150,000 and £200,000. It will take about two years to construct.

Commencing operations on this scheme is significant in view of the long depression, as it indicates that this firm at least has no fear for the future of shipbuilding and repairing. It is noteworthy also that this firm proposes to build a large motor cargo steamer at its Wallsend yard in order to give employment to the staff and workpeople. This vessel, it is understood, is to be built on the firm's own account, and will be the third built by the same company during the shipbuilding depression under similar circumstances. The only other work at present in hand is the two destroyers ordered a few months ago, and the firm is to be congratulated on its enterprise, which could well be emulated by others.

The fifth State Electric Power Station in U.S.S.R. has discovered a new method for burning peat. This method consists in using duck peat as a layer, together with plain peat, thus reaching a result of 90 tons of steam p.h. against 70—75 obtained by the use of plain peat.

New Marine Engine Required.

In view of the statement by Mr. Andrew Hamilton at a recent meeting of the Tees-side Branch of the North-east Coast Institution of Shipbuilders and Engineers, the announcement that the Moor Line, Ltd., of Newcastle, has ordered two 8,500-ton deadweight capacity cargo vessels, which will be engined by White's Engineering Co., Ltd., Hebburn-on-Tyne, is significant. Mr. Hamilton emphasised the need of a new prime mover to ensure a complete rejuvenation of shipping. Just as the Parson's turbine came in about twenty-five years ago, at a time when higher power, speed, and economy were in demand, so a prime mover was needed to-day. Engineers in this country, and particularly on the Continent, were carefully investigating the possibilities of the improved steam engine.

The White engine, with which these two new vessels are to be engined, is a combined marine steam engine and turbine, and is in fact a new type of engine for which important claims are made. These include 15 to 20% increase of speed on the same fuel consumption, or, alternatively, the maintenance of present speeds with over 30% reduction in fuel consumption. These engines will be the first of their type to be applied to commercial use, and their performance will be watched with more than ordinary interest. The vessels are to be built by the Burntisland Shipbuilding Co., Ltd.

Brighter Outlook at Barrow.

The announcement by Commander Craven, managing director of Vickers Armstrong's shipyard at Barrow, that an order has been received for a Brazilian training vessel indicates a much brighter outlook for Barrow workers. Commander Craven hopes that three further ships will be under construction in a few months' time. Although the prospects for passenger shipbuilding, which would have an important influence in reducing unemployment, are not very encouraging, this company's activities render Barrow workpeople relatively fortunate, for shortly the stocks will have a first-class cruiser, a large British submarine, three Portuguese submarines, and a Brazilian training ship in course of construction.

It is difficult to say how many workmen will be absorbed by this work, but it shows that no effort is being spared to restore this shipyard to its normal state of busy-ness. We believe this to be a prelude to a more successful year than this company has experienced for some time.

Steel Company Modifies Wage Cuts.

Evidence of a slight improvement in the iron and steel industry is indicated by the decision of the directors of the United Steel Companies, Ltd., to restore 25% of a wage reduction suffered by the various staffs in June, 1931. At that time depression in the industry was intense, and it was considered necessary to reduce the wages of all members of the central and branch staffs. The directors have recently reconsidered the position, and in view of an increased trading profit, mainly resulting from economies achieved in working, have restored wages to the extent mentioned.

This decision embraces the staffs at four works in Sheffield, two at Scunthorpe, two at Workington, the Rothervale Collieries, Treeton, and Thomas Butlin and Co., at Wellingborough.

Institute of Metals May Lecture.

The President of the Société des Ingénieur Civils de France, M. Albert Portevin, has accepted the invitation of the Institute of Metals Council to give the next annual May lecture before the Institute. M. Portevin has chosen as the title of his discourse "Quenching and Tempering Phenomena in Alloys." The lecture will be delivered on Wednesday, May 10, at the Institution of Mechanical Engineers, Storey's Gate, Westminster, commencing at 8 p.m. Visitors are invited. Cards of admission are obtainable from the Secretary of the Institute of Metals, who reports that applications for membership are flowing in much more freely than was the case when England was on the gold standard. Over 30% of the new members reside in U.S.A., where the Institute's subscription rate, when converted into dollars, looks particularly attractive.

The Institute, which this year celebrates the twenty-fifth anniversary of its foundation, will hold its annual general meeting in London on March 8–9. Upwards of a dozen papers will then be presented for discussion. In the evening of March 8 the annual dinner will be held, under the chairmanship of Sir Henry Fowler, K.B.E., LL.D., D.Sc., the President of the Institute. Sir Henry is now in Egypt attending the International Railway Congress at Cairo.

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Ferro Silicon— Basis 10%, scale 3/- per unit	ton	5	17	6
20/30% basis 25%, scale 3/6 per unit	„	8	10	0
45/50% basis 45%, scale 5/- per unit	„	13	15	0
70/80% basis 75%, scale 7/- per unit	„	19	0	0
90/95% basis 90%, scale 10/- per unit	„	30	0	0
§ Silico Manganese 65/75% Mn., basis 65% Mn.	„	14	17	6
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
Ferro Phosphorus, 20-25%	ton	18	15	6

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Foundry No. 1	3	10	0	
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Foundry No. 1	3	1	0	
„ No. 3	2	18	6	
„ No. 4	2	17	6	
Cleveland— Foundry No. 3	2	18	6	
„ No. 4	2	17	6	
Silicon Iron	3	1	0	
Forge No. 4	2	17	0	
Midlands— N. Staffs Forge No. 4	3	1	0	
„ Foundry No. 3	3	6	0	
Northants— Forge No. 4	2	17	6	
Foundry No. 3	3	2	6	
Derbyshire Forge	3	1	0	
„ Foundry No. 3	3	6	0	
West Coast Hematite	3	6	0	
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Lead	9	0	0
Heavy Steel— S. Wales	2	0	0
Scotland	1	17	6
Cleveland	2	0	0
Cast Iron— Midlands	1	16	0
S. Wales	2	2	0
Cleveland	2	1	0
Steel Turnings— Cleveland	1	12	6
Midlands	1	0	6
Cast Iron Borings— Cleveland	1	3	6
Scotland	1	12	0

SPELTER.

G.O.B. Official	—		
Hard	£12	10	0
English	15	15	0
India	14	0	0
Re-melted	14	10	0

STEEL.

Ship, Bridge, and Tank Plates— Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	9	0	0
„ „ (Marine) „	—		
„ „ (Land), N.E. Coast	10	0	0
„ „ (Marine) „	10	10	0
Angles, Scotland	8	7	6
„ North-East Coast	8	7	6
„ Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	0	0
Light Rails £8 10 0 to	8	15	0
Sheffield— Siemens Acid Billets	9	2	6
Hard Basic £8 2 6 and	8	12	6
Medium Basic £6 12 6 and	7	2	6
Soft Basic	6	0	0
Hoops £9 10 0 to	9	15	0
Manchester— Hoops £9 0 0 to	10	0	0
Scotland, Sheets 24 B.G.	10	5	0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten.	lb. 2/-
Finished Bars 18% Tungsten.	„ 2/9
Extras	
Round and Squares, ⅛ in. to ½ in.	„ 3d.
Under ¼ in. to ⅞ in.	„ 1/-
Round and Squares 3 in.	„ 4d.
Flats under 1 in. × ⅛ in.	„ 3d.
„ „ ⅛ in. × ½ in.	„ 1/-

TIN.

Standard Cash	£147	0	0
English	148	5	0
Australian	150	0	0
Eastern	152	0	0
Tin Plates I.C. 20 × 14 box	0	16	0
Block Tin (Cash)	146	7	6

ZINC.

English Sheets	£24	10	0
Rods	27	0	0
Battery Plates	—		

* McKechnie Brothers, Ltd., quoted Jan. 11. † C. Clifford & Son, Ltd., quoted Jan. 11. ‡ Murex Limited, quoted Jan. 11.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.
§ Prices quoted Jan. 12, ex warehouse.